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Research Article

Framework for capacity based sustainable design & development: towards resilient communities

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Abstract The most fundamental struggle for realizing a sustainable built environment still lies in the use of non-renewable resources in its articulation. Although efforts have been taken to increase the use of sustainable materials the vast majority of the building sector still relies heavily on depletable resources. This article debates that the most fundamental contributors to sustainable development are the evaluation and incorporation of inhabitant capacities. Evaluating the available natural materials, inhabitant skills and tools could play a fundamental role in creating sustainable solutions. However, inhabitant capacity-models insufficiently cover all instrumental capacities into one model (both inhabitant and community). Therefore, this article describes: a framework for evaluating inhabitant capacities; how to map available resource capacities; how these capacities can be incorporated into sustainable housing development and planning. The framework was developed as a part of a support tool, which helps designers and engineers to evaluate inhabitant capacities. To describe the framework and support tool a rural Sub-Saharan community is used, as their capacities are relatively less complicated compared to a 'western' context. The article concludes that the framework shows great potential in reducing the use of unsustainable materials. Furthermore, that it could enable social sustainability by creating self-reliant and resilient communities.

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1. Introduction

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The author's overall research is situated on Mt. Elgon, rural Kenya. As an architect he was trying to articulate improved

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housing and general infrastructure for over a decade, however the community there is still struggling to achieve an improved Quality of Life (Cobb, 2000). Out of all life necessities, housing proves to be a crucial threshold in realizing an improved Quality of Life (QoL) and is therefore the aim of the overall research. Moreover, due to its current level of development the communities have a relatively less complicated housing situation in comparison with urban or western contexts. Additionally, the Mt. Elgon locality proves an exemplary situation for comparable developing societies on the continent.

Research previously performed by the Smits, 2017 identified that an important factor to the decreasing level of inhabitant self-reliance¹ towards their housing and thus, lowering the QoL, is the introduction of manufactured building materials and non-local building technologies. Not only do the inhabitants seem not to have the financial resources to afford such solutions, they also lack the knowledge, skills and tools. In this previously performed research this inadequacy is pinpointed as a fundamental shift from independent (local materials, tools and skills) towards dependent development (non-local materials, tools and skills). Here, the author presented the traditional housing knowledge as a collective and embedded knowledge (Cromley, 2008), carried within a community of practice (Cox Callister, 2013; Tovivich, 2011).

As the (traditional) housing mainly deployed existing inhabitant capacities it enabled a high capability to maintain, extend or replicate the housing (Smits, 2017) by oneself. However, the building solutions introduced to the inhabitants on Mt. Elgon seemed to ignore existing capacities and heavily rely on external capacities, resulting in a low capability to maintain, extend or replicate the housing by its inhabitants. Capacities, which McKnight and Kretzmann (1996) called individual capacities, identify the richness of skills, talents, knowledge, and experience of people in low-income neighbourhoods (1996, p.4).

As this disparity in capacities is only observed by the author (hypothesis) the second article (Smits, 2019) investigated if a mismatch existed between the current and desired housing capacities of inhabitants on Mt. Elgon. To analyse the housing situation on Mt. Elgon, the research deployed an extensive survey amongst two hundred households, which was held in February 2017. The article confirmed that the majority of inhabitants on Mt. Elgon live in challenging circumstances (physical and financial). Despite that, results show they have a very similar notion of desired housing, although this house does not suit their current capacities. Almost half of all the participants estimate that they won't be able to afford their desired housing. Moreover, they rely on external help to offer alternative housing solutions that do meet their capacities.

Due to the specificity of the required capacity evaluation, the author assumed (second hypothesis) that such a method did not exist yet and needed to be designed and developed. The third article (Smits, 2019) therefore, presented the framework in which the impact and success of

the support could be measured. Describing the targeted goal (realizing housing with increased inhabitant self-reliance), procedures and guidelines. As the quasi-experiment would be conducted in a vulnerable community, that article describes extensive ethical guidelines. In this (fourth) article the actual support is being developed. As the inhabitants (also called clients) lack the capacities to articulate improved housing within their capacities by themselves, they rely on the external help. The support is therefore developed for designers and engineers (hence called: the support tool user) from outside the community.

As many support manuals, methods and strategies already exist, the article firstly presents the literature review of tools developed before and after the year 2000. Moreover, it investigates tools specifically developed for designers and engineers operating in vulnerable context or stimulate community/inhabitant participation. Secondly, it presents the findings and key-components of the literature review confirmed the author's hypothesis, that a support tool for inhabitant capacity evaluation did not yet existed. Although some components are available in literature, the key components are missing. Thirdly, the article describes the key-components which not yet existed specially for inhabitant capacities: observation, interview, decision-making, planning and knowledge transfer. The findings of this article were used to describe a concept version of the support, which was tested in situ (2017). In a consecutive article the author will address the impact and success of the support tool.

2. Literature review

Inhabitant capacity comprehension and integration in the articulation of solutions will require a higher level of engineering training. This is mainly due to it requiring a complicated comparison between a multitude of factors: social, cultural, financial, material, spatial, environmental and climatological. Leading to results articulated in the built environment and seem most appropriate for architects. However, as argued in previously performed research by the author, many architects involved in development aid often have limited experience and does their training (education) not suite the requirements to work in vulnerable environments. Although architects working in vulnerable communities are much needed, due to the non-commercial character, adapting architecture education to these requirements is simply not viable. Therefore, the next sections reviews the literature of past and current support tools related to realizing housing in comparable contexts.

2.1. Support tools before 2000

A huge portion of all the support tools, toolkits and manuals meant for people operating in vulnerable housing development contexts was developed by the United Nations Centre for Human Settlements (Habitat). Starting at the mid-seventies till the late 1990s, many practical manuals were developed to support local operating engineers in implementing alternative construction technologies (Raghavan, 2001). Many publications focussed on alternative materialization with earth and required equipment

¹ Self-reliance: the ability to independently provide a qualitative built environment on one's own powers, knowledge, materials and construction methodologies (UNHCR, 2005).

(UN-Habitat, 1975, 1986, 1987a, 1987b), describing the practical implication of applying those solutions in a development context. It however, does not support the engineer to weigh the suitability of this solution within a given context. Neither does it assess if the applied solution is transferred and owned by the involved local stakeholders.

However, there were many manuals developed to provide trainings in alternative construction technology (UN-Habitat, 1991, 1997). Emphasizing on the role of municipal agencies (UN-Habitat, 1991) and in many cases providing tools to execute trainings on a national level. Involving government and province stakeholders in providing improved shelter solutions (Fisher and Tees, 1994; UN-Habitat, 1988, 1991, 1997). Therefore, not effectively involving inhabitants in adopting and applying offered knowledge locally.

In the same period UN-Habitat established a network of African countries to share policies, approaches, frameworks and manuals in the field of local building materials and technologies. The results were shared via the journal of the network of African countries on local building materials and technologies. Most of the issues aimed at identifying alternatives for portland-cement building products, although introducing other industrialised products, there was an overall criticism of imported materials to supply the local market in Africa. Just like the previous paragraph most of the journal issues aimed at offering solutions on a 'governmental level', specifically on energy reduction strategies or health risks.

Leading up to the HABITAT II conference (1996) it became clear that NGOs were becoming important local players to offer housing solutions to inhabitants. In the same time NGOs started to gather their own knowledge and experience, developing them into support tools. Therefore, in 1988 HABITAT started to publish these results in an effort to make an overview of the best practices within one catalogue (UN-Habitat, 1988). Providing training programmes (Wynn, 1986), evaluation frameworks for developed projects (Rugh, 1987), courses for architecture students to engage in real-life impoverished communities (Ast, 1979, 1982), an elaborate overview of activities for community involvement (Ellis, 1983), small scale material production (Smith, 1986; Spiropoulos, 1985 and German Appropriate Technology Exchange. 1985; Webb, 1986), alternative housing solutions and practical step by step manuals to train or advise inhabitants on alternative building solutions (Batchelder, 1985; Grupo Mills, 1981; Talpuy, 1984). Although the combined publications form an interesting and useful body of knowledge, they do not provide with one directly applicable framework to help architects working in vulnerable communities.

Even though UN-Habitat was by far the largest international organization articulating shelter development support around the world, there are others that published equally important and useful manuals. For example the Peace Corps, which released an extensive manual for development in remote areas (Peace Corps, 1964). Explaining theories on social anthropology and development, best practices on agronomy, horticulture and closing with a large section on self-help engineering and housing

(although brief). In their homemaking handbook, they help volunteers in practical tools to evaluate and stimulate livelihood conditions in relation to home development (Peace Peace Corps, 1971).

Afterwards, more practical engineering manuals were developed for self-help construction (Gallant, 1977), how to make tools (Christians and Zubrowski, 1981), building homes of earth (Peace Peace Corps, 1981) and bamboo (McClure, 1982). Equally to UN-Habitat the Peace Corps also developed some manuals on managing projects (Wzorek, 1987) and toolkits for building capacity (Peace Peace Corps, 2002). However, in comparison to UN-Habitat, the majority of the developed tools are applicable to volunteers in the (rural) field and are hands-on.

Due to the extensive number and scope of other developed manuals, toolkits, approaches and methods, making any generalizations is futile. However, similar observations can be made as discussed in past paragraphs, namely in four categories. Firstly, solely focus on practical materials solutions ((Rigassi, 1985). Secondly, offer solutions through local production of materials and tools (Acioly, 1992). Thirdly, through national or governmental training (Council of Europe, 2005). Fourthly, are theoretical and not directly applicable into working context (Cole and Lorch, 2003). This does not mean that the sum of all available information could not compile to an appropriate support tool, however, the efforts made to compile the information often remains on the level of a catalogue (UN-Habitat, 1988), directory (UN-Habitat, 1997) or bibliography (Raghavan, 2001).

One manual stands out from all of the studied tools: the design & management of community projects – a team approach (Hubbard and Ennis-Applegate, 1988). Although the manual was mainly tested in three pilot workshops on government extension staff, NGOs and community leaders, the structure, topics, methods and handouts are directly applicable. Addressing key topics in project development (theory, trainings, etc.), execute a needs assessment (mapping, observation, interview, focus-groups, etc.), make a project planning (problem solving, goals, objectives, action plan, planning, testing, etc.), implementation (management and monitoring) and evaluation/measuring the impact. The next section will focus on the literature review of support tools developed after 2000.

2.2. Support tools after 2000

This section will address different types of support tools within three different groups: general volunteer tools (preparing, management, monitoring and impact), tools developed for engineers and architects working in vulnerable contexts and tools for community/inhabitant participation.

2.3. General volunteer tools

General volunteer tools provide the notions, theories and approaches needed for anyone operating in vulnerable communities. Examples are: volunteer management toolkit (UK Department of Health, 2016), project design manual

(Thomet and Vozza, 2010), Resilient Development Practical Guide (Cavero, 2018), Volunteer Handbook (Habitat for Humanity; Peace Corps, 2017). Although these manuals help volunteers to prepare, plan, monitor and evaluate projects, they are limited in explaining practical issues, for example: appropriate behaviour, communication and clothing.

Inhabitant self-reliance in relation to the introduced aid was extensively debated at the end of the 1990s and the decades after (Campfens, 1997; Oakley, 1991; Saugstad, 2001; Shuman, 1998). However, their outcomes; approaches, strategies, case study, theories and tendencies; often remain generic. Making it difficult to apply them directly in the field. One of the most elaborate publications on self-reliance in relation to housing was published by UNHCR (2005). This handbook consisting of two volumes elaborates on the importance of self-reliance, applicable toolkits describing step by step how to evaluate self-reliance and how to promote and support this through development. The books are written in the context of refugees and mainly address trainings on a governmental level. The support for application in the field is limited and does not actually evaluate inhabitant self-reliance. Although the presented tools have useful components, they are in their articulation not useable for engineers and architects operating in vulnerable contexts.

2.4. Tools for engineers and architects working in vulnerable contexts

This category elaborates on a broad scope of available tools in the field of engineering in the built environment and architecture. This broad scope is set as many tools are not specifically created for housing design or development, however, provide with useful frameworks, approaches and methods. The Sustainable Building Assessment Tool (SBAT) is the first category of directly applicable impact tools. A version of the tool was developed in South Africa (Gibberd, 2001), to help assessing how buildings can support sustainability in developing countries. Evaluating environmental, economic and social indicators, emphasizing on aspects like: locality of used materials and inhabitant participation. However, only presenting scores of projects and not explaining the weighing of factors. Moreover, the tool itself is not available and is therefore not applicable in the field.

Later versions of the SBAT (Residential Design 1.04, Gilbert, 2015), became increasingly commercial. This follows the trend in the development of SBATs (U.S. Department of the Interior, 2009; Burdová et al., 2015) which are often emphasizing on commercial projects, excluding important social and cultural factors. Moreover, the SBATs available for developing countries are difficult to apply in different contexts (Bhatt et al., 2012) and lack precision for individual inhabitants & community capacities.

The second category focuses on empowerment and self-help. The National Slum Dwellers Federation in India give an elaborate overview of case studies, executing various tools and methods (survey, mapping, house modelling, etc.) for empowerment (Patel, 2004). However, briefly addresses applied methods & tools making it difficult to know the

specifics to implement advised approaches in the field. Other underline the importance and key factors of empowerment (Pattison et al., 2011), describe global innovative government organizations (Mitlin and Satterthwaite, 2013), policies (Mullen, 1999) and the role of inhabitant empowerment by architects (Serageldin, 1997), which again sadly remains on a general explanatory level.

An important aspect of inhabitant empowerment in the field of housing is to stimulate self-help. *The manual for organized self-help housing densification in Eastlands, Nairobi* (Makachia, 2005), explains how to analyse existing context and articulate a self-help design based on inhabitant capacities. Elaborating on the used methodologies, process and outcomes. An equally extensive investigation was made by Davidson and Payne, 2000, although targeting communities, not individual inhabitants. A similar approach was used in the study: *Improvement of housing conditions and the performance of an aided housing scheme in selected rural areas of Kenya* (Müller and Job, 2006). Presenting a detailed analysis of a housing scheme in rural Kenya; explaining the methods to map and identify housing needs; examining the financial sustainability of the underlying mortgage system and identifying the main drivers. This could be used in locating the right inhabitants within a larger area to offer support. However, it solely targets financial drivers (mortgage attribution). Most of the developed self-help support focuses on developing and evaluating policies for enabling self-help housing (Arroyo, 2013) or present cases which are not applicable to development context (Benson and Hamiduddin, 2017).

The third category describes the role of design. One of the most well-known books in the field of anthropological housing analysis is Amos Rapoport (1969). How he analyses existing living conditions and functions of communities around the world is a great inspiration for anyone involved in rural housing development. *Ground rules in humanitarian design* (Chun and Brisson, 2015), Is a collection of articles and cases in the field of Humanitarian design. Outlining an important framework for designing for impoverished communities, integrating culture, art, architecture, economy, ecology, health, and education. Although the individual cases present interesting insights, they do not offer a structured approach for architects operating in the field. In *Affordable house designs to improve health in rural Africa: a field study from north-eastern Tanzania* (von Seidlein et al., 2017) six prototypes houses were designed and built from lightweight and natural materials. The described methodology focused mainly on mosquito and temperature reduction. The study *Flexible Design and Construction Strategies for Self-Help Housing in Botswana* (Jobe and Williams, 2016) has a similar approach in analysing context and articulating a design. However, inhabitant empowerment (participation) is low, here the involved engineers and architects articulated a solution based on the parameters chosen by them, not considering the wide range of inhabitant abilities and desires towards their housing needs.

Do It Yourself (DIY) manuals is a somewhat strange category in this section. In this category manuals are described that have a practical directly applicable use for engineers and architects operating in the field. The book most frequently used by architects in the field is: *The*

barefoot architect (Lengen, 2008). It describes all the basics needed to understand climate, available materials, construction, energy and sanitation. Using simple sketches and brief explanations Lengen provides with a tremendous scope of tools and methods, ranging from making basic soil test to weaving lightweight separation walls. Although similar attempts have been made they either focus only on one part of the building process, are not applicable in other contexts or lack inhabitant involvement in the decision-making process.

2.5. Tools for community/inhabitant participation

The last category focuses on tools that emphasize on community and inhabitant participation. Inhabitant participation and bottom-up approaches are crucial to project sustainability (Sherman and Ford, 2014). *Community participation methods in design and planning* (Sanoff, 2000) is still the most elaborate guide how to involve communities into design processes. This guide written from the professional's perspective elaborates extensively on case studies around the world and in detail describing used tools and techniques (questionnaires, manuals, etc.). Including housing project in both urban and rural environments. A similar more contemporary study by Hofmann (2014), evaluates recent case studies, explaining the used approaches and methodologies. This study, however, remains on a general level and does not offer the tools and techniques used, therefore, make it difficult to copy them for own application. Both publications fail to provide a framework, which tools and techniques could be used in a given context. Caroline Clark (2001) does offer a toolkit for the self-assessment of partnerships in community participation, however, does not offer the tools and techniques needed to stimulate participatory processes in the actual planned activities.

3. Findings of the literature review

The literature review shows that at this moment a practical guide for architects realizing housing based on capacities does not exist. Therefore, this section highlights the key literature to be used in articulating the required design support. Two of the most thorough manuals are: *Engineering for sustainable human development: a guide to successful small-scale community projects* (Amadei, 2014) and *Field guide to environmental engineering for development workers* (Mihelcic et al., 2009). They both introduce a framework to help engineers conduct small-scale projects in vulnerable communities. Combining concepts and tools traditionally used by development agencies with techniques from engineering project management and systems thinking.

Both guides include many general theories, methods, tools and examples, moreover, are useful in the field helping vulnerable communities. However, they do not elaborate on housing development, lack practical explanation, do not focus on inhabitant capacities and miss a focus on inhabitant self-reliance. Both guides do present an excellent framework to structure a potential improved or new tool. From the engineering and architectural point of

view the *barefoot architect* (Lengen, 2008) provides many of the missing practical issues needed to work (design, test, experiment and build) in the field. However, it misses the methodologies and practical handouts on the design and management of community projects. Which are offered in *The Design & Management of Community Projects - A Team Approach* (Hubbard and Ennis-Applegate, 1988). Compiling all these elements together leaves one topic open: community participation. Here, the catalogue of training and information tools on community participation in human settlements (UN-Habitat, 1988) and *Community participation methods in design and planning* (Sanoff, 2000) offer the required methods and approaches. Based on these findings the next section will describe the identified key components of the design support.

3.1. The key components of the design support

Based on the literature review findings presented in the previous section, this one describes the key-components, organized according to previously studied frameworks (Amadei, 2014; Lengen, 2008; Peace Corps, 1964). If there were no tools for inhabitant capacity evaluation and integration the components marked in bold (capacity evaluation and integration) are those developed by the author and briefly introduced in the next section:

- Key Topics (Sanoff, 2000; Thomet and Vozza, 2010, UNHCR, 2005): addresses the main goal (towards their self-reliant housing development), objectives and topics. It's meant to increase understanding in the underlying motivates, theories and aims of the overall support.
- Sensitive context approach (Liamputong, 2006): explains the sensitivity of working in a vulnerable community. Elaborating on desirable: behaviour, documentation, clothing and such. This section is meant for people who never worked in a vulnerable rural community before.
- Daily routine, interview (Creswell, 2003; von Seidlein et al., 2017): is meant to get a first understanding over every day activities. Increases understanding of cultural and social differences, moreover, helps preparing in later stages of, mapping and observation.
- Dream-house-game (Ellis, 1983; Granath, 2001; Hofmann, 2014; Lee, 2006; Sanders et al., 2010): this participatory section helps to understand the desires and preferences of the entire family. This will be used in a later state to project the actual inhabitant capacities on.
- Preparatory house and context mapping (Gallant, 1977; Lengen, 2008; Rapoport, 1969): explains how to make an extensive site survey. Starting with the general basics for people who never made such a survey. Later on elaborating on specific elements that need to be analysed in preparation for the capacity.
- Inhabitant capacity evaluation, observations (Thakur, 2016; Toffin, 1994): In addition to the context mapping an in-depth understanding of daily activities and spatial usage is needed. This section attributes the theories on observation and how this needs to be conducted in this type of context.
- Context depth analysis (Karanja, 2010): explains how to make an extensive site survey. Starting with the general basics for people who never made such a survey. Later on,

elaborating on specific elements that will need to be analysed in preparation for the capacity.

- **Inhabitant capacity evaluation, interviews** (Creswell, 2003; von Seidlein et al., 2017): is the final step in getting a full understanding of all the existing capacities of the inhabitants, relatives and community members. Compiling a list of all skills, materials and tools available.

- **Capacity-informed decision-making** (gap: methodology does not exist): based on the identified capacities this section helps to articulate three design propositions and developing them with the family to a final design.

- **Planning with inhabitant capacities:** with a project based on available capacities, most of the elements needed to construct the dwelling needs to be collected, borrowed, harvested and such. This is a time-consuming effort unknown in regular project processes. This section helps to plan the activities and needed capacities.

- **Training & Effective knowledge transfer** (Fisher and Tees, 1994; UN-Habitat, 1997; Wynn, 1986): knowledge transfer to the inhabitants is the most crucial factor in their ability to maintain, extend or replicate to offered solution (materials, construction and design). This section will help to register the existing skill levels and plan trainings accordingly on the job.

4. Inhabitants' proximal and peripheral capacity evaluation framework

In this section, the author describes the key components of the support tool which were not yet available. All new key components developed by the author evaluate inhabitant capacities and aim at integrating them into solutions articulation. The author makes a distinction between the capacities inhabitants possess themselves (proximal capacities) and the ones which are available in there direct surroundings (peripheral capacities) which are either borrowed/exchanged with community members or are freely available in nature. Some of these capacities are easy to observe and identify for both the inhabitant and support tool user: a hammer or saw can easily be found within the household and are directly related to the production of housing. The same counts for income or available resources such as: thatch, soil or wood. However, there are many capacities that are less obvious. Some capacities like tools, skills and resources are not directly related to the production of housing. This section uses the literature from the previous section to describe the key components required in the tool for the evaluation of proximal and peripheral inhabitant capacity evaluation.

4.1. Observing inhabitants on their proximal capacities

A known approach to understand the client's spatial requirements is through the analysis of their existing use of the house. Besides the physical elements and their function (inventoried through spatial mapping), there are also many behavioural elements. Both are required to grasp what preferences the family has and how/where they prefer to perform them. Resulting in a very detailed understanding

what the clients prefer to do, where, when and how (for example where they wash, prepare food, fetch water, dry clothing, etc.). In these every day activities capacities can be observed that are highly useful in alternative building methods, therefore, the support tool advises to use the observation as it is a suitable methodology to systematically record people's behaviour, actions and interactions in their daily activities (Hennink et al., 2010).

The presence of someone from outside the family or community in a vulnerable context can have a tremendous effect on the inhabitant's behaviour. This might influence it and ultimately the support tool user might misplace or misread the inhabitant's capacities. Therefore, to get an in-depth understanding, it is important to evaluate the inhabitants before actively engaging. The level of engagement of the observer can normally range between participating fully in everyday activities (participant observation) and not participating at all in any activities (non-participant) observation. Although, it is commonly argued that not participating in practice does not exists, as the presence of an observer (person/camera/recorder) always forces a level of participation.

Non-participant observation might theoretically give the most objective results, however, the presence of the observer might suppress regular every day activities of the inhabitant (Hennink et al., 2010). On the other hand, full participation in everyday activities (helping, asking, sharing, etc.) changes the behaviour as well. Therefore, the support uses a partially engaged participant observation. Here, the observer can help in everyday activities, however, is requested to only engage in a supporting role (not sharing ideas, perspectives, etc.). To get a broad understanding on the capacities of the entire family, every family member will need to be observed for one whole weekday and one weekend day.

Based on maps previously made by the user (Section 3) the observer is able to mark where each capacity is registered (Fig. 1). To help the observer note the various capacities a registration sheet was made to track the activities and related capacities during observations (Table 1). Everyday activities such as cooking, cleaning, washing, water fetching, etc. show the inhabitants physical capacities (resources and tools) and how they are used in activities (skills). Although observed capacities might not directly connect to the built environment the observer is able to register them and later decide on its possible use. At the end of the observation the observer is asked to add a picture, sketch or plan that explains, locates or proofs the described activities and capacities.

Another important finding of the observation is to get a first notion of the social structures of the family (which shared activities do they have). These structures play a vital role in evaluating proximal capacities to the family. On a later moment, identified families can be interviewed and their capacities evaluated. The next section will describe how the found capacities can be confirmed and understood through interviews.

4.2. Interview inhabitants on proximal and peripheral capacities

After observing the family and their community, the support tool user has a large inventory of capacities. The

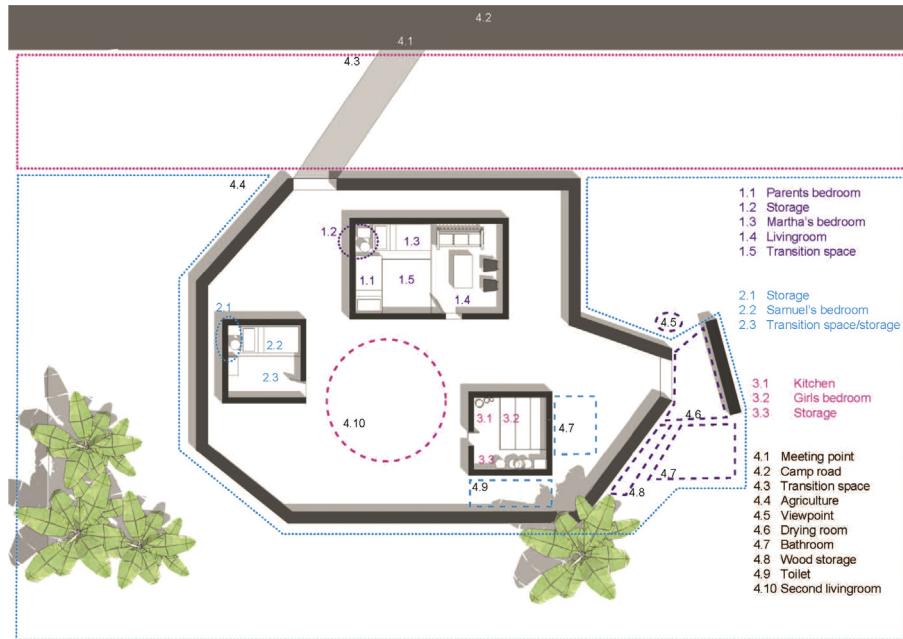


Fig. 1 Example of a family compound on Mt Elgon (Smits, 2017).

interview section intends to help the user to explore them in detail (ownership, costs, reward, quantity, etc.) by interviewing the inhabitants. The support tool advises the support tool user to setup a semi-structured interview (Hennink et al., 2010). An informal or unstructured interview would give too much room for free interpretation and might cause blind spots in the capacity analysis. A structured interview would be too formal and might limit the information the inhabitants are willing to share on their capacities. An in-depth interview would allow too much detailed information about the capacities. Although very valuable, in this phase concisely described or quantified resource, tool and skill capacities are needed (Table 2).

The support helps the user prepare an interview instruction (based on a given example), which helps them to organize the interview. The instruction section assures that the interviewee is at ease (location, sitting, etc.) and understands the purpose of the interview (aim, topics, etc.). The interview guide section helps the support tool user to transform the found capacities (from the observation) into logical questions for the interview. The questions of the interview guide are organized in four sections:

- resources
- tools
- skills/knowledge
- income/labour

The support provides with a manual how to transcribe the interviews afterwards. This helps the support tool user to go through the answers afterwards and fill in a complete overview of all the capacities. After interviewing the family, the user is requested to repeat the process with the identified friends, family and community members that have certain capacities. The outcomes of these interviews help understand the conditions in which families and families are willing to share their capacities. As a result, the

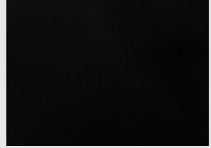
support tool user will have a wide scope of available capacities and their conditions. The next section will describe how these capacities can be used in what the author coined as capacity-informed decision-making.

4.3. Capacity-informed decision-making

The core argument of this article is that the main contributor to sustainable design is the use of available, proximal and peripheral capacities in articulating the built environment. As argued before, capacities are complex and difficult to evaluate. Therefore, this article described the key components of a support tool that could help evaluate those capacities via a mixed method approach. This section elaborates on the most important steps in the support that describes how these capacities can be used in, what the author calls, capacity-informed decision-making. Here, the departure point for the design process is not defined by the functions, size or aesthetics, but by the available capacities of the family and their community.

In earlier sections of the support (not mentioned in this article) the support tool user organized 'sessions' with the family evaluating their desired house. The outcomes of this part will describe their desired: house typology, building methodology and materials. These are used to inform the support tool user to compare the desired capacities (by the family) with their actual existing capacities. In the example shown in Table 3 the desired foundation phase was chosen of a family with extremely low financial capacities (less than 20.000 Ksh - representative for the area on Mt. Elgon) to build an entire house. Red indicates the problematic desired materials (costly materials and/or transportation). In the right columns the support tool user is able to list possible alternative materials found in the capacity analysis that are within the inhabitants reach. This will enable the

Table 1 Example empty observation sheet (Smits, 2017).

Time	Activity	Duration	Where	With Whom	Skills, Tools, materials	Problems/ chances/ solutions	Comments	Map/Plan/Sketch/Picture
05:00	Arrival							
05:15	Praying	10 min	Inside main house	Parents – together				
05:25	Getting dressed	5 min	Inside Main house	Alone	–	Clothes are stored in a box in the living room	–	
05:30	Making fire	5 min	Inside Main house	Alone	Fire making matches & wood	–	–	
05:35	Washing	5 min	Outside In front of main house	Alone	Bucket, soap, water	By hand	–	
05:40	Waking up children	5 min	Kitchen structure	Alone	–	All daughters sleep inside the kitchen structure with the youngest brother.		
05:45	Making tea	15 min		Alone	Mixing and stirring Pan, water, tea, milk & sugar			

Note: TEAM: 1; OBSERVATION: MOTHER; DATE: 21-08-2017.

Table 2 Example, overview capacities: materials (Smits, 2017).

nr	Item	Amount	Unit	Comments	Ownership	Name of the owner	Payment	If payed: specify	Distance
1	clay soil	unlimited		soil for making walls	family		free		none
2	timber	5	st	$d = 15 \text{ cm}, l = 3 \text{ m}$	family		free		1 km
3	wood: post	11	st	$150 \text{ mm in diameter}, l = 3-4 \text{ m}$	family		free		2 km
4	dried grass	150	bundle	s (suitable for roofing)	family		free		1 km
5	window	2	st	windows with iron bars $50 \times 60\text{cm}$	family		free		none
6	door + frame	1	st	ironsheet door with wooden frame	family		free		none
7	water	unlimited	bucket	waterpoint	community	common	free	free: fill up the whole with other soil	500 m
8	clay soil	unlimited		rocks for the foundation	community	Francis Kibue	free		500 m
9	rocks	unlimited			community	common	free		1 km
10	timber	15	st		community	Francis Kibue	paid		2 km
11	wood: post	5	st		community	Francis Kibue	paid		2 km
12	dried grass	50	bundle		community	Francis Kibue	paid		2 km
13	cement	unlimited	bag		other	shop	paid		5 km

user to discuss alternative materials with the family, exchanging ideas and elaborating on why certain desired materials might be less suitable (considering family's capacities) and what possible alternatives are.

To make sure sufficient alternative materials for the new house are being considered, the support tool users are advised to make at least 2 alternatives. However, with alternative building materials come alternative tools, labour and skills. Therefore, the support explains how to generate an overview of the alternatives on all the capacities: resources, tools, skills/knowledge and income/labour. In Table 4 an example of the alternative building tools list is presented to show the differences in required capacities. The financial capacity is solely given to indicate how much the capacity would cost in case it is not available.

After formulating at least two alternative solutions, the support tools user is asked to prepare a presentation for the family. The support tool user presents a sketch design based on capacities: resources, tools, skills/knowledge and income/labour. The typology, program and aesthetics of the sketch house are not considered in this presentation, solely the capacities. Per sketch design the support tool user are asked to clearly show what the needed capacities are and to what extent they suit the existing capacities of the family. After the presentation, there is an informal unstructured interview where the family can address all their questions and remarks about the presented designs. Allowing them to indicate the elements they like about the individual designs and which they would like to include in their future house. The last part of the support advises the support tool user to gather all the results from the presentation and interview session and combine them into a final recommendation for the design phase. It contains all the resources, tools and labour that could be used in making the design.

The support does not elaborate on how the capacities should be used in articulating a design. The tools are developed for users with a background in engineering and design. The support provides with a departure point for the design process through: context analysis, inventory inhabitant capacities and weighing them against alternatives building solutions. However, designing and building based on available proximal and peripheral capacities is complex and extremely difficult to organize. Tools have to be borrowed, materials ex-changed and labour meticulously planned (which activity, when and who will help with it). Therefore, the next section describes the planning methodology.

4.4. Planning with (proximal and peripheral) capacities

With the design finalised and approved by the family, the planning of the building activities can begin. The user/community capacity & participation planning section of the support describes how the support tool user can approach it. Step-by-step the process is unravelled roughly into five phases: foundation, floor, walls, roof and finishes. Per building activity, the support tool user states the necessary capacities: materials, tools and labour, indicating who (from the earlier made capacity analysis) has offered to

Table 3 Weighing alternatives – materials (Smits, 2017).

Materials (Needed)	Quantities	Available	Transport	Materials (Alternative)	Quantities	Available	Transport
Branches	15 m	yes	0	Branches	15 m	yes	0
Marram Soil	1.32 m ³	yes	500	Marram Soil	1.32 m ³	yes	0
Cement	1396 kg	no	500	Clay soil	1.5 m ³	yes	0
Riversand	2.828 m ³	no	1000	Soil	2.828 m ³	yes	0
Brick	600	no	1000	Stones	300	yes	0
Small Ballast (1/4 inch)	0.6996 m ³	no	400	Marram Soil	0.6996 m ³	yes	0
Transparent hose	8 m	no	0	Transparent hose	8 m	no	0
Mixed Soil	3 m ³	yes	0	Mixed Soil	3 m ³	yes	0
String	22 m	no	0	Sisal rope	22 m	yes	0

help and for what reward. When the planning is finished the support tool user discusses the planning with the family and makes corrections if necessary (dates might not fit, resources might not be available, etc.). When the planning is finalised, the planning needs to be presented to the community members that are listed in it. Per community member, a small letter will be handed out stating what is requested, by when and for what reward. The community members are asked to reply to the letter or ask any questions they might have. They are given time to discuss the requested capacities with their family members before they agree.

As families struggle to generate the financial capacities to pay for help by the community, it is extremely important to enable the inhabitants to trade capacities instead of paying for them, offering each other a better habitation without the need for large savings and investments. This system of exchanging materials, labour and tools (capacities) has been practiced for centuries and has contributed substantially to the level of self-reliance. Most of the inhabitants on Mt. Elgon do not have the luxury to help each other without asking for something in return. Therefore, the last step of the support describes a registration system

(logbook) where all borrowed capacities (tools, materials, labour) are registered in. At the end of each day, a logbook is used to register the shared capacities. This can be a certain number of hours of digging, giving back six wooden posts by the end of the year, or a bag of maize by the end of the harvest season. This way is allowing a more flexible exchange system that follows the fluctuations in income, harvest and available time, finally empowering the community to plan and realize a more self-reliant and improved built environment.

4.5. Transfer of knowledge capacities

One of the most essential inhabitant capacities towards their housing are their available knowledge and skills. The tool intends to support the team to help inhabitants in articulating alternative housing solutions, they will most likely need to introduce new ways of constructing. This section (which was added after printing the support for the experiment) intends to help the user to describe: the roles, the current skill levels, desired skill levels (skill gap evaluation), planning of skill training and tracking the learning effect.

Table 4 Weighing alternatives – tools cost (Smits, 2017).

Tools (Needed)		h	Available	Costs/Reward	Sum
1	Measure (ruler, tape: 1m = 0,5 h)	11	no	1100	4800
	Shovel (1m ³ = 8 h)	130.42	yes		
	Compacter (1m ² = 0,5 h)	12.1	yes	200	
	Measure volume unit (container, wheelbarrel)	2	yes		
	Trovel & flatboard	54	no	3500	
2				4800	
	Measure (ruler, tape: 1m = 0,5 h)	6	no	1100	3300
	Shovel (1m ³ = 8 h)	130.42	yes		
	Compacter (1m ² = 0,5 h)	12.1	yes	200	
	Measure volume unit (container, wheelbarrel)	2	yes		
3	Stone Hammer	26	no	2000	
				3300	
	Measure (with feet: 1m = 0,5 h)	6	no	0	200
	Shovel (1m ³ = 8 h)	130.42	yes		
	Compacter (1m ² = 0,5 h)	12.1	yes	200	
	Measure volume unit (container, wheelbarrel)	2	yes		
	Break with stones	26	yes	0	
				200	

Table 5 Example of skill level descriptions in a research/design activity.

Existing Skill level	Improvement needed?	Desired Skill level	Teaching direction	Difference in Skill level	Teaching Activity 1	Depth of Knowledge %	Teaching Activity 2	Depth of Knowledge %
3 Proficient	no		Inhabitant- Team	1	4-4,5: Demonstration: practical (inhabitant-community member) 4-4,5: Demonstration: practical (inhabitant-community member)	80	4,5-5: Consecutive practical (inhabitant-community member) 4,5-5: Consecutive practical (inhabitant-community member)	90
3 Proficient	yes	4 Expert	Team-Inhabitant	1	4-4,5: Demonstration: practical (inhabitant-community member) 1-1,5: Reading book or tekst	80	4,5-5: Consecutive practical (inhabitant-community member) 1,5-2: Viewing video or pictures	90
0 Unknowing yes	yes	2 Familiar	Team-Inhabitant	2	2-2,5: Instruction practical (tutor-inhabitant)	20	2,5-3: Demonstration: practical (tutor-inhabitant)	50
1 Beginner	yes	2 Familiar	Team-Inhabitant	1	4-4,5: Demonstration: practical (inhabitant-community member) 2-2,5: Instruction practical (tutor-inhabitant)	40	4,5-5: Consecutive practical (inhabitant-community member) 4,5-5: Consecutive practical (inhabitant-community member)	90
4 Expert	no		Inhabitant- Team	1	4-4,5: Demonstration: practical (inhabitant-community member) 4-4,5: Demonstration: practical (inhabitant-community member)	80	4,5-5: Consecutive practical (inhabitant-community member) 4,5-5: Consecutive practical (inhabitant-community member)	90
4 Expert	no		Inhabitant- Team	1	4-4,5: Demonstration: practical (inhabitant-community member) 4-4,5: Demonstration: practical (inhabitant-community member)	80	4,5-5: Consecutive practical (inhabitant-community member) 4,5-5: Consecutive practical (inhabitant-community member)	90
4 Expert	no		Inhabitant- Team	1	3-3,5: Consecutive practical (tutor-inhabitant)	60	3,5-4: Observed practical (tutor-inhabitant)	70
3 Familiar	yes	5 Expert	Team-Inhabitant	2				

In the previous section the building activities of the building project were identified. The first step of the knowledge transfer helps the user to identify the roles which are connected to activity. Narrowing down in which area the skills are expected to be available. As roles and related skills can vary strongly between different contexts it's difficult to generalize them. To understand what the user of the support believes to be the skill levels the next step in the support helps them to describe what they perceive to be the skills levels on a five-point Likert (Norman, 2010) scale. Providing a point of measurement for the user to evaluate the existing skill levels of the inhabitant(s). Based on the inventory made of existing inhabitant capacities (previous parts of the support) the users can now identify the existing skill levels and estimate the required skill levels for the building activities they planned (see Table 5). Moreover, if the identified skill is transferred from the user to the inhabitant or the other way around.

The next step helped the user to plan teaching and training activities. Based on Dale's cone (Davis and Summers, 2015) on teaching activities, the author described a ladder of teaching methods according to the inhabitant's skills level. Although the Dale's theory (Dale, 1969) has been debated (Lord, 2007) and disputed (Subramony, 2002) extensively, it does match the existing method of knowledge training in the community. In previous publications the author presented how this knowledge is largely embedded (Cromley, 2008) and shared within a community of practice. Here, most of the learning activities take place in Learning on the Job (LoJ) and are taught on the job (ToJ). However, is Learning by Instruction (LbI) an uncommon learning activity within the community and only practiced in formalised (vocational) school training. Although Dale argues that LbI is an ineffective form of learning, it does provide with fundamental knowledge (theories) required for executing building activities. For this reason, the author describes 5 different levels with teaching methods for LbI category:

(skill level 0–0,5) Verbal Instructions: Tutor explains to inhabitants how to execute task. Gives general notions/theory on a certain activity.

(skill level 0,5-1) Verbal instruction with demonstration: Tutor explains to inhabitants how to execute task. Gives general notions/theory on a certain activity. Shows with attributes how the task should be performed.

(skill level 1–1,5) Reading book or text: Tutor explains why/how a given book or text adds understanding on activity or task. Inhabitant reads.

(skill level 1,5-2) Viewing video or pictures: Tutor explains why/how a given video or picture adds understanding on activity or task. Inhabitant views.

(skill level 2–2,5) Practical instruction: Tutor shows and explains how a specific activity/task should be performed. Inhabitant tries to replicate without help (learning from mistakes).

In the LoJ category the average level skills are situated. Here, the trainee knows the theory (knowledge) behind the skill and had instructed trainings in multiple events (basic skills). In the learning on the job section, methodologies are used to gain more in-depth understanding of the skill while performing it on the job. The trainer will slowly let

Table 6 Example of planning and evaluating the construction of a house.

Day	Activity nr.	Activity	Skill	Duration	Teaching direction	Starting Skill Level	Targeted Skill Level	Teaching Activity	Teaching Impact	What did you train	photo	Feedback Coach	Decision Trainee
18-Oct	6.1	Foundation Wall	Masonry: mixing wall mortar	1 h	Team- Inhabitant	2 Familiar	3 Proficient	2-2,5: Practical instruction	2-2,5	Corné and Damian explained how the mortar ratios can be easily measured and how the mixing should be performed. Cleophas and Stella helped in the mixing.		The group is happy and ready to start the teaching day. Corné has the didactus skills to make people feel comfortable however, they have difficulties to follow the explanation sometimes. I suggest that maybe cleophas can translate what is said to swahili which solves the problem	The group is clearly ready to start training on higher levels. We might skip some levels as the group is happy and comfortable however, they have to start practising by themselves.
19-Oct	6.2	Foundation Wall	Masonry: laying wall brick	6 h	Team- Inhabitant	0 Unknowing	1 Beginner	0,5-1: Verbal instruction with demonstration	0,5-1	Corné started with a short instruction in reserved room in the community. Explaining the basics of brick dimensions, the thickness of needed mortar (stability). Afterwards we showed a short movie about masonry works	 	The groups feels distant and passive, they have difficulties to follow what is said although Cleophas is translating. I suggest to grab some bricks so they understand the dimensions and we use cardboard to show the different levels of mortar indicating the strength of the mortar. Especially the cardboard really works as they can feel the difference in strength.	After a brief discussion we decided to ask cleophas to join IN this way the group finds it easier to address quistions or doubts they have.

Note: TRAINING REGISTRATION PHASE: Preparation & Position; TRAINER: Corné, Damian (coach); TRAINEE(S): Cleophas & Stella, some interested community members; BUILDING WEEK: 3.

the trainee work by himself. By the end of the LoJ section the trainee can work independently. The following categories are identified:

(skill level 2,5-3) Demonstration, practical (tutor-inhabitant): Tutor shows and explains how a specific activity/task should be performed within a practical setting. Inhabitant observes and asks questions.

(skill level 3–3,5) Consecutive practical (tutor-inhabitant): Tutor and Inhabitant work consecutively on the same activity/task within a practical setting.

(skill level 3,5-4) Observed practical (tutor-inhabitant): Inhabitant shows and explains how a specific activity/task should be performed within a practical setting. Tutor observes and asks questions.

The third category is for the highest skill levels. Here, the trainee understands the theory behind the skill, had multiple instructed trainings, had multiple on the job trainings and has gained independency. The trainee is able to reproduce activity independently without instructions from the trainer. The trainings can now focus on training the trainee to reproduce the knowledge to others. Here, the trainee will be able to train their community members and exchange the gained knowledge effectively. The following categories are identified ([Scientific Integrity Committee, 2012](#)):

(skill level 4–4,5) Demonstration: practical (inhabitant-community member): Inhabitant shows and explains how a specific activity/task should be performed within a practical setting. Community member observes and asks questions. Tutor observes and comments.

(skill level 4,5) Consecutive practical (inhabitant-community member): Inhabitant shows and explains how a specific activity/task should be performed within a practical setting. Community member observes and asks questions. Tutor observes and comments.

(skill level 5) Observed practical (inhabitant-community member): Community member shows and explains how a specific activity/task should be performed within a practical setting. Inhabitant observes and asks questions. Tutor observes and gives feedback afterwards.

Based on the existing skill level the type of training can be selected accordingly. In the excel file the training methods are sorted by skill level. Organizing consecutive trainings will enable the user to effectively plan the skill level of the family/community. [Table 6](#) shows and answer sheet of the planned training of various skills, its execution and pictures of the activities. Allowing the support user to keep track of executed activities and accomplished skill improvements. Providing a blueprint of training activities for future projects in the community.

5. Conclusion

In previous publications the author elaborated on the importance of inhabitant capacity evaluation for sustainable design and development. The literature review section of this article described many existing tools that are available however, it showed that there is a lack of a suitable tool to evaluate available, proximal and peripheral inhabitant capacities. Hence the goal: to develop a

framework in order to help designers and engineers to advise rural communities in developing countries how they can realize self-reliant housing solutions based on their existing capacities.

The outcomes of the literature review pinpointed the necessary key-components for the support, in order to articulate self-reliant housing solutions in vulnerable context. Both the framework (order of methods) as some of the key-components were adopted from existing tools. However, some of the key-components were not yet available, especially those that involved inhabitant capacities. Here, most of the methods were available (observation, interview, planning and training), however, were not specific to inhabitant capacities. The article therefore described the necessary additions and adjustments to integrate inhabitant capacity into the support tool components.

The results of this article were used to develop the concept version of the support tool which was tested in Sub-Saharan Africa in late 2017. In a consecutive article the impact and success of the support will be presented. The outcomes (key components & framework) of this article therefore cannot be used yet in other situations.

6. Limitations

The article describes the necessary key-components of the support tool and the parts that were developed by the author. These parts are very descriptive as they intend to develop a new specific approach of the described method. These outcomes were used to develop a concept version of the support in order to test the support in a quasi-experiment setting ([Shadish et al., 2002](#)) in Sub-Saharan Africa in late 2017.

In the first iteration (postdoctoral research) of the support, the impact and success will be used to improve the support. It is the author's intent to have two iterations before considering the support for publication.

Although the concept support tool was finished in 2017 and was tested in 2017–2018, the success and impact are so elaborate that they require another article to expand on the overall key factors, their correlation, methods and experiment design before the result can be presented.

As the support tool was written to assess inhabitant capacities in rural Sub-Saharan Africa, it can't yet be used in another context. However, the framework itself could be used to evaluate available inhabitant, proximal and peripheral capacities in different contexts.

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