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SUSTAINABLE CONSTRUCTION IN CONFLICT-AFFECTED CONTEXT: A DESIGN-ASSISTANCE TOOL TO ENHANCE HUMANITARIAN IMPACT ASSESSMENT AND PERFORMANCE.

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ABSTRACT

The humanitarian sector is committing towards a green transition of their operations, in order to contribute to the global fight to climate change. To implement such change a scale within construction operations, a sustainable construction and design-assistance tool has been developed to support humanitarian staff and local actors in adopting appropriate solutions all along the project life cycle. Tailored onto complex construction projects as, for instance, healthcare facilities, the tool pilot has been organized around five project phases. There are: 1) site analysis; 2) concept design; 3) developed design; 4) verification of design, procurement and implementation; 5) handover and operational phase, With a first rolled out planned within the ICRC, the tool is intended to reach the broader humanitarian audience.

KEYWORDS
Humanitarian projects; sustainable construction; tool; decision-making; conflict-affected context.

INTRODUCTION

The world is facing the non-ignorable challenge of climate change, resulting in irreversible impacts on the environment and on our society. Such impact is unequally distributed, with the most vulnerable social groups –as civil society within weaker economies, displaced populations, the urban poor, and conflict-affected groups - also resulting as the most exposed. This dramatic dichotomy stems from the so-called environmental injustice (or justice) concept, introduced by Dr. Bullard over forty years ago with the encompassing aim to address unequal societal impact distribution with regards to climate, energy, environment, nutrition, health and more among the society (Agyeman et al., 2003). Such concept is still of absolute relevance, when looking at the impact of industrial sectors benefitting the strongest economy while severely impacting the most vulnerable populations. It is the case of the construction sector, responsible for almost 40% of global CO_2 emissions, and therefore heavily contributing to climate change and its resulting major threats to vulnerable populations displaced by disaster, famines and draught. (Habert et al., 2020, (UNEP, 2021)

The humanitarian sector, with its primary objective consisting in safeguarding the lives of endangered people and to alleviating suffering through prevention and rescue measures, is therefore committing towards a green transition of their operations. This pledge is reflected in multiple initiatives of individual organizations, all of which contribute to the overarching vision of the Climate and Environment Charter for Humanitarian Organizations, lead by the ICRC and the IFRC (ICRC & IFRC, 2021) and grounded into the holistic approach to sustainability in the so called Global South, as universally established and recognized by the UN Sustainable Development Goals (United Nations, 2016). By contributing to the fight against climate change, the signatory agencies not only aim to pave the way for mainstream adoption of more sustainable practices but also indirectly target the benefit of the sector itself, potentially mitigating the impact of the environmental crises and therefore also reducing the vulnerability of the beneficiary populations. For doing so, it significantly relies on construction-related operations, both in shelter-related programs as well as in healthcare, educational and other types of activities. The role of the construction sector in humanitarian missions, and specifically its adaptation to a greener sector, becomes therefore a topic of interest, especially in view of its dual role of key resolutive sector, but also of responsible trigger of climate change (Bajželj et al., 2013). Finally, it is important to mention that the construction sector is not a stand-alone one, as it is significantly entrenched with different resource extraction and transport, including water, therefore resulting in a chain of impacts extending far beyond the building footprint expressed in CO_2 emissions. On a more positive note, it is though to be reminded that the sector is also known for its potential to act as an agent of positive regenerative change, as it can trigger the economy, enhance resiliency and foster health and wellbeing for the society and the planet at once (Celentano, 2021; Celentano, Habert, et al., 2020; Gou & Xie, 2017; Zhang et al., 2015)

The global picture therefore calls for an urgent action, combining the climate emergency with the commitment of the humanitarian sector to improve its performance in this direction. There is therefore a solid interest for the development of sustainability tools and guidelines tailored around the specific needs and obstacles of interest for humanitarian operations. Existing technologies and frameworks, fully suitable in a non-humanitarian context, are in fact hardly apt in this specific context, and therefore more tailored solutions are required. The relevance of this approach is grounded in recent research, which has shown the importance of identifying sustainable approaches and methods specifically targeting the built environment of the development and humanitarian sector (Celentano, 2021; Celentano, Göswein, et al., 2020; Celentano, Habert, et al., 2020; Celentano & Habert, 2021;)

The present paper aims to present the preliminary results of a collaborative project between the International Committee of the Red Cross ICRC (Water and Habitat Unit), the Swiss Federal Institute of Technology at the ETH Zurich (Chair of Sustainable Construction) and the École Polytechnique Fédérale de Lausanne EPFL (Building2050 Group), targeting the development of a design-assistance tool supporting humanitarian actors in the construction field towards a more sustainable practice.

JUSTIFICATION FOR DEVELOPING A NEW TOOL

A broad range of tools and assessment methods have been developed to support and enhance sustainability in the construction sector (Cisar & Habert, 2017), with some specifically addressing context of scarce resources in the Global South (Du Plessis et al., 2007; Muller, 2016). The majority of assessment systems available re usually intended for headquarters of companies in Northern countries and fail to consider the specific actions and needs in Global South, nor to say in conflicted area where ICRC operates. The tracking of sustainable operation and maintenance is usually done through the development of smart buildings with sensors and monitoring. Although quite promising, this seems to be far from possible application in ICRC context and relying on local communities and stakeholders on the ground has much more additional benefits. Finally, the consideration of regenerative thinking where assessment try to promote solutions that would create more benefits than less harm is usually not promoted in sustainable standards. They promote reducing harm, while regenerative design promotes maximizing benefits. Few regenerative design framework have been developed and are usually very qualitative (Hes and Du Plessis. 2014).

The reason for the development of the new sustainable design assistance tool here presented therefore has a specific rationale, as it stems from a direct request of the ICRC and the observation of a gap in the market offer.

Such request is grounded in a few key gaps identified within the current market offer:

- Coverage of conflict and crises-specific aspects (ex: exposure to disaster, consideration for discontinuous availability of resource supply as of water and energy, ..)
- Coverage of the whole project life cycle, including: site analysis, design phase, operational phase (the last being mostly neglected by the existing tools)
- Avoidance of sensitive data input requirement (ex: project plans)
- Global usability, providing for site-related feedback and quantitative assessment
- Light requirements in terms of system operation and data accessibility.

The first item is indeed the major driver, with no current existing tool being suitable for addressing the specific socio-technical operational context of conflict, and protracted crises affected areas. For instance, in general building sustainability labels may not be readily applicable to the construction work of humanitarian organizations, as they've been developed with regard to specific national economic and industrial contexts. In particular, widely-used labels such as LEED and the Building Research Establishment Environmental Assessment Method (BREEAM) address the context of developed economies equipped with mostly sophisticated building industries. As such, their framework may not be relevant to less-developed and unstable contexts of humanitarian assistance.(Bui et al., 2016; Fu et al., 2014) This contextual connotation results in a two-folded approach. At first, it results in the inclusion of specific considerations usually not addressed by available tools (ex: discontinuous access to water and energy, possible presence of unexploded ordeals during rubble removal), as well as by the removal of elements unsuitable within the context (ex: community-based participatory approach). Moreover, as significant bottlenecks in humanitarian construction project success were identified, via focus group, in its operational phase due to capacity gaps, communication discontinuity and cultural and behavioral barriers, a section of the tool was allocated specifically to cover for the operational phase of the project.

The avoidance of sensitive data input requirement is also strongly connected to the delicate operational context of the assessed projects. This element was of relevance in the tool design phase, as it was a key determinant for the selection of input data within the tool. For instance, project plans and precise project location were not considered safe for use, and therefore a simplified approach was developed to be able to provide for quantitative and site-stepcific infromation without depending on such data.

Beyond that, as expressed by Alyami et al. with regards to the development of a sustainable assessment framework suitable for South Arabia (Alyami & Rezgui, 2012), most of the environmental assessment methods have been designed to suit a specific territory, as per their original conception. Their accurate applicability to all regions is therefore faulty, if not impossible. More specifically, the authors identified certain environmental factors which may hinder the direct use of any existing environmental assessment globally, as: Climatic conditions, Potential for renewable energy gain, Resource consumption (such as water and energy), construction materials and techniques used, and more. In addition, the accessibility of available quantitative sustainability assessment methods in terms of economic cost, softwares or competences required to implement them, pose an additional challenge to their adoption at scale. A few years after the work of Alyami et al., this statement is still valid, although the market now offers tools, as EDGE (International Finance Corporation, 2022) tackling a global use and inclusive of elements of consideration for the Global South, although still based in prevalence on Europe-specific data. While this shines the light on the potential largescale outreach of sustainability assessment and benchmarking systems in a broader context, still it is not specifically tailored to conflict-affected areas. The pilot tool development, which is the object of this paper, therefore aimed to target such gaps, proposing a pilot solution via an iterative process of co-design inclusive of academic and humanitarian stakeholders, as thoroughly explained in the upcoming section Tool development methodology.

TOOL SCOPE, OUTLINE AND STRUCTURE

The tool is conceived as an instrument of support with regards to sustainability, serving Architects and Engineers in charge of medium to large scale construction projects in contexts affected by protracted crises and conflict. Its core focus is to provide for sustainability guidance and assessment, thus conceived both as quantitative analysis (systematic evaluation of the project impact along the whole project cycle) and qualitative (set of recommendations, feedback and checklists to support a more informed decision-making process). Through the whole project cycle, from early design to operational phase, it explores the project sustainability with regards to: design and material guidelines, carbon emissions, energy use and optimization, water use and management, waste management as well as maintenance and handover recommendations, accounting for environmental, social and economic indications.

SUSTAINABILITY COVERAGE: MULTI-OBJECTIVE OPTIMIZATION APPROACH

Strongly centered on the specific impact of construction and design-related decisions in the project development, the tool addresses a set of components expanding beyond the absolute construction domain. This approach, resulting in a multi-objective optimization, is grounded on the regenerative approach presented in the introduction, which finds its focus in the maximization of the positive impacts of a systemic transformation, rather than in the reduction of its impacts in isolation.
For this reason, and especially stemming from the consultations with the ICRC actors, the following topics have been considered along the diverse tool phases:

- Climate assessment, inclusive of hazard-specific considerations of relevance in the design phase
- Design specific feedback and guidance considering typological and climatic influences
- Influence weighing of building materiality and window proportion on internal comfort.
- CO2 emissions assessment and reduction (related to material production and transport)
- Material selection and comparison
- Estimation of energy demand, efficiency enhancement and system optimization
- Solar potential analysis and PV system assessment
- Water management optimization, inclusive of water harvesting potential assessment, water tank calculator and considerations on contextual factors as material water intensity, water pollution risk from construction and local water scarcity (at the moment under development)
- Waste management optimization, with a specific focus on construction waste and end-of-life scenarios
- Maintenance and monitoring plan facilitation and optimization, so to guarantee appropriate efficiency of the facility over its operational phase.

All aspects mentioned have been explored in a context-informed way, where the element in discussion is always declined within in local socio-technical dimension based on the project location.

DEFINITION OF EXPECTED USER AND PLANNED ACCESSIBILITY

The pilot tool targets construction project managers, as well as architects and engineers involved in other capacities in construction projects in the humanitarian setting (for example: head of unit). With a planned non-commercial use, it is conceived as an open source tool for all humanitarian organizations involved in construction projects. As for its pilot stage, it is currently distributed only within the ICRC.

TOOL STRUCTURE

The tool is structured along five project phases, and is intended to be utilized progressively along the whole project cycle, with its starting point being the completion of the project feasibility study.
The five use phases, based on the ICRC project workflow, can be briefly described as follows:
PHASE 1 – Site analysis

The first phase of the tool is designed to inform the user about the climatic conditions at the project site and the associated design-specific consequences.
To access this phase, the user should have already completed the project feasibility study, and therefore be aware of the project location and function. No specific planning information are yet required.

PHASE 2 – Concept design

This phase will provide for an early design project assessment based on specific inputs. It will inform on energy demand, environmental impact assessment and comfort.
To access this phase, the user should already have a first architectural design with defined geometry, spatial program, construction and non-detailed materiality. The user may already have an estimate about the expected electricity demand

PHASE 3 - Developed design

Phase 3 is composed out of three main topics (Material Analysis; Water Demand and Harvesting Potential Analysis; PV Analysis) and will provide for a detailed design project assessment based on specific inputs.
To access this phase, the user should have an elaborated architectural design with knowledge of the exact materiality (layered structure of the structural elements), functionality, the technical details and the exact operational phase program, inclusive of expected number of users and associated system consumption and requirements.

PHASE 4 – Verification of design, procurement and implementation

Phase 4 addresses the transition between detailed design and construction phase via three subsequent work-blocks: verification of design, procurement, implementation. To do so, this phase, currently in draft , is conceived so to be compiled and validated both by the main user (international humanitarian actor) and by the local partner (local facility or program manager). Verification of developed design supports the socio-cultural and technical evaluation of the appropriacy of the design choice. After design is verified, Phase 4 supports informed decision on material procurement, contractor selection and material purchase with regards to sustainability. For this reason, to access this phase, the final design needs to be at this point secured, but material purchase should have not start yet.

PHASE 5 – Handover and use phase

Phase 5 is the final tool phase, including advisory on maintenance, optimal operation, monitoring and building end-of-life scenario. Also shared between the humanitarian and local user, it covers both technical elements related to the construction specifics, as well as components of energy, water and waste management. The tool coverage of the operational phase, at its embrional stage at the moment of this paper drafting, follows the overall approach of enhancing the user's capacity and knowledge concurring towards the project sustainability. For this reason, Phase 5 includes collection of lessons learned with regards to project criticalities, failures and maintenance protocols as well as the corresponding resolutive actions and impacts. This organized user-generated knowledge creates the base of reference to establish and share recommendations, best practices and feedback, and is reverted back to the users as new projects are created, based on their region and program. This analytical component of Phase 5, crossing information from previous projects, aims to enhance the organization capacity for future projects, incrementally over time.

A simplified scheme of the phases content, required data, and provided assessment is described in Figure 1.

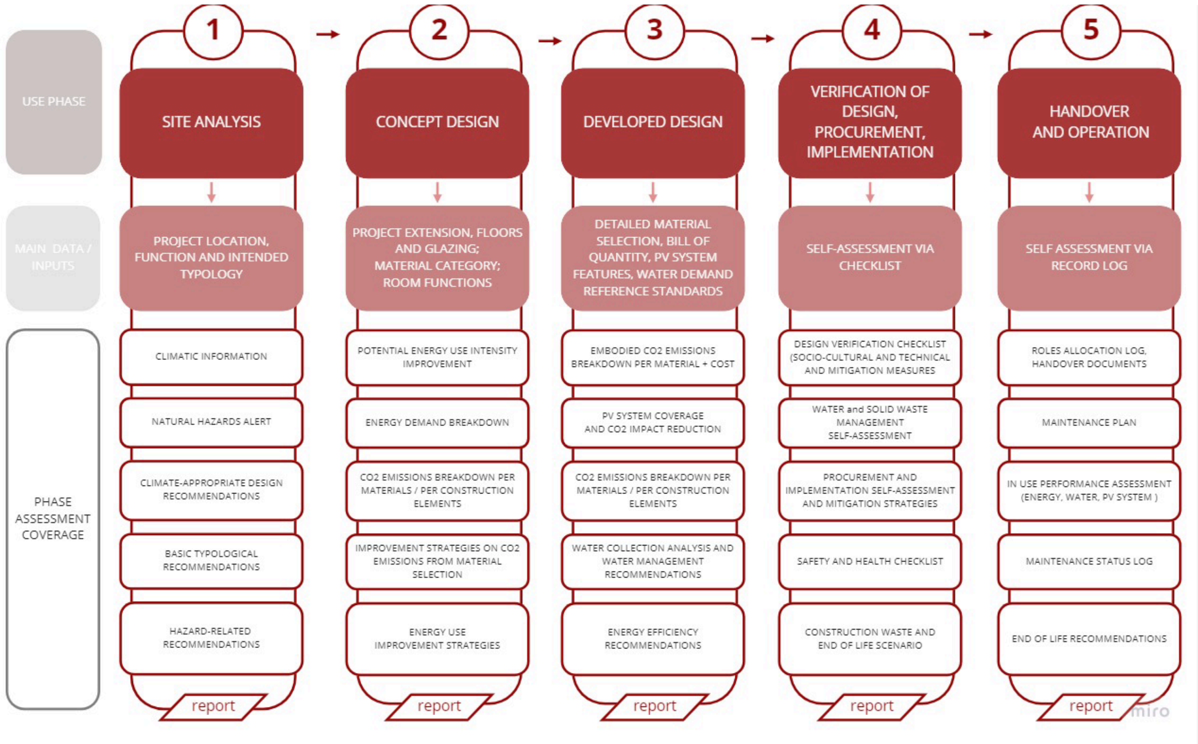

Figure 1: Sustainable design-assistance tool structure and assessment coverage scheme

DATA
Based on the above mentioned sustainability coverage components, data from diverse sources have been collected and compiled.
Specific data sources are available upon request and can be found in the Tool User Manual, with the exception of technical information shared by the ICRC based on completed projects.
The table below provides for a summary of the major data references.

Table 1: summary of main data sources

Data	**Detail**	**Source**
Climatic Data and Solar Data	Typical Meteorological Year (TMY); data set with hourly values for a whole year.	Collected Data from Climate.OneBuilding.Org (Published by a variety of organizations)
Precipitation	Measured precipitation data from 1980 to present	(NASA, 2022)
Seismic Data	global seismic hazard as peak ground acceleration (pga)	(Swiss Federal Institute of TechnologyTechnonology ETH Zurich, 1999)
Design Guidelines	Passive design improvement strategies (text)	Climate Consultant, (ICRC, 2016, 2020)
Materials – CO_2 emissions	Emissions related to extraction, production and transport (country specific) of Materials	generated values based on Ecoinvent Database (Ecoinvent, 2022) based on (Zea Escamilla & Habert, 2017) and further transformed

Energy Demand	Function-specific electricity demand for lighting and equipment	Swiss Technical Specification; SIA 2024;2021
Electricity – CO_2 emissions	Country-specific emissions related to electricity production (medium and low voltages)	generated values based on Ecoinvent Database (Ecoinvent, 2022)
Water demand	Standards for minimal required water demand	SPHERE (The Sphere Project, 2011) MSF's hospital standards for sub-Saharan countries
PV CO_2	Emissions related to PV-produced electricity	KBOB (KBOB, 2022)

TOOL DEVELOPMENT METHODOLOGY

The Tool was developed applying the design-thinking approach, which led to iterations of its components prior to rollout. Such components, articulated in a series of subsequent activities, can be grouped into: Literature review phase and Need Assessment; User journey design, Content development, Back and Front-end development and in-interim review, Planned rollout. This process was conceived

LITERATURE REVIEW PHASE AND NEED ASSESSMENT

The first work block consisted of a mixed literature review, complemented by a context and need assessment carried out via focus group with ICRC personnel.

Literature review comprised of:

- Systematic scientific review and comparative assessment of eight sustainability assessment methods, these being: LEED, BREEAM, EDGE (Excellence in Design for Greater Efficiencies), SBTool (Sustainable Building Tool), DGNB (Deutsche Gesellschaft für Nachhaltiges Bauen), SNBS (Standard Nachhaltiges Bauen Schweiz), HQE (International) (Haute Qualité Environnementale), and QSAND (Quantifying Sustainability in the Aftermath of Natural Disasters). Specifically, this part was developed by the EPFL, and details on the findings can be found in
- Integrative literature review on construction programs in conflict-affected areas and of documents from the ICRC and other humanitarian sector including: ICRC Water and Habitat project technical information, engineering and architectural guidelines and construction protocols, reports and Architectural and Engineering design and project management guidelines.

The Context and Need assessment was carried out in a form of focus group with ICRC Construction Project Managers and other delegates with construction-related responsibilities. This aimed to prioritize operational sustainability components of relevance for the project, and to identify contextual socio-technical barriers to optimal project implementation and causes of project failures and major hazards.

USER JOURNEY DESIGN

Based on the review phase findings, a user journey, intended as the experience the user have when interacting with the tool, was then defined. More specifically, this was centred on the idea of a progressive use of the tool, articulated around subsequential project life cycle phases covering its development from site analysis to operational phase , as more thoroughly described in the section Tool structure. The steps required by the user, the topics covered, and the provided feedback were described in a visual User Journey Map, which facilitated the review phase.

CONTENT DEVELOPMENT

The identified areas of interest within the theoretical frameworks of sustainability in construction were then operationalized, and progressively developed into the tool content. The content development work-block was coordinated by ETHZ, and informed by the findings of the review phase. The specific areas of coverage of sustainability, presented in the next section Sustainability Coverage, were declined

along the different project phases and concretized in terms of content. The content includes a simplified Life Cycle Assessment (LCA) expressed in CO_2 emissions, and based on
Subsequently, a review of existing tools and plugins relevant for the desired content of the tool was performed. The following were identified as relevant tools; Climate Consultant, Ladybug Tools, NOAA Solar Calculation, and Neat+.

The required datasets were then identified, collected and compiled, in accordance with the drafted User Journey. A significant component of this phase consisted in generate a simplified data set, based on the analysis of built project of the ICRC, in order to feed the tool with reference values within the early assessment phase. Based on a simplified parametric analysis, the influences of few design iterations in different climatic zones, and the influence of building shape, could be therefore evaluated and utilized to generate qualitative feedback of relevance for the project . Such iterations covered, for instance, Window Wall Ratio, glazing type and the material performance based on its thermal transmittance
The software used in this process were Excel, Rhinoceros, Grasshopper and Ladybug tools.

BACK AND FRONT-END DEVELOPMENT AND IN-INTERIM REVIEW
Exc-based calculation sheets were finally compiled and shared with the software developers, so to support back-end implementation. Both back and basic front-end development were outsourced to Design to Production GMBH, with the intention of obtaining a functional tool, although to be considered a mock up, or pilot project, suitable for large scale testing.
One-to-one experts meetings within ICRC staff accompanied the development, especially in its in-interim review moments. These took place after each phase release, accommodating for integration of feedback from the sample group within the ICRC before the final pilot launch phase.

CURRENT STAGE, FINAL REVIEW AND ROLLOUT
With a pilot launch planned by mid-June –just around the present conference time- the tool is currently comprehensive of its whole five use phases, although pending a round of review and subsequent edits both from the development team, and from an ICRC sample group.
Given the extension of the tool relevance along different project phases, and within the global context, the launch is planned at first within the ICRC, after a final round of review with ICRC personnel and subsequent corrections. a launch of the tool, to be intended as a functional pilot, is planned at first within the ICRC, over the course of three months to one year period, and followed by a review session from the users. This first rollout will serve as basis for the next project phases, with the intention of reaching to a broader audience within the humanitarian sector, comprehensive of diverse international organizations.
A number of aspect of interest for the next project pilot upgrade have already been identified, as:

- development of benchmarking system for project evaluation;
- integration of water consumption demand per material and technology;
- integration of broader hazard-related data;
- diversification of user profiles based on data clearance level definition;
- development of analytical assessment of in-use project data for failure prediction, preventive planning and associated budget.

IDENTIFIED OBSTACLES, ADOPTED RESOLUTIVE ACTIONS AND CURRENT STATUS

While it is important to remind that the project scope consists in the development of a pilot tool , some specific aspects of it have presented obstacles of major difficulty, and might require rework.
These most critical ones are here listed, together with the adopted strategy to overcome them

Table 2: summary of main identified obstacles to the tool development, and adopted resolutive actions.

IDENTIFIED OBSTACLE	ADOPTED RESOLUTIVE ACTION
availability of relevant country-specific data	use of global database (ex: for climatic data) and/or country-based values (ex: for CO2 emissions) combined with precise user inputs based on project location
simplification of the user journey and reduction of data input from the user	evaluation of the user experience via consultation with ICRC personelle during the project development
availability of standard values for energy consumption depending on both building function and location	reference values can be collected via the tool during the building operational phase, and information can be crossed based on region, climate and/or function
production of quantitative assessment on CO2 emissions and energy consumption while avoiding sensitive data input as project plans	progressive clearance of required user-provided input with ICRC + parametric approach allowing the calculation of results for different provided solutions (ex: pre-definition of a set of possible Window/Wall Ratio alternatives, and of building typologies)

While the adopted measures seem to lead in the right direction, at the current stage, it will be necessary to collect feedback after the pilot tool rollout to confirm their effective validity.

CONCLUSION AND OUTCOME

The paper presented a collaborative project between ETH Zurich, EPFL and the ICRC with regards to the development of a design assistance tool, supporting sustainable construction in conflict and crises-affected context. The tool is conceived as an instrument of support for architects and engineers in charge of medium to large scale projects such as, for instance, healthcare and educational facilities. Its core focus is to provide sustainability assistance, this being provided both as support in the evaluation of the project impacts along the whole project cycle, and as a set of recommendations and guidance to support a more informed decision-making process. Through the whole project cycle, from site analysis to the monitoring phase, it comprises of qualitative and quantitative evaluations and explores the project sustainability with regards to: design and material guidelines, carbon emissions, energy use and optimization, water use and management, waste management as well as maintenance and handover recommendations, accounting for environmental, social and economic indications.

This publication covered the rationales behind the tool relevance, scope, development phases, its structure and coverage of sustainability components, as well as the prevailing data and methods utilized for its development. Indications on future steps, identified bottlenecks and further planned improvement were also presented.

The interest for this project resulted as two folded, one being operative and the other being scientific. In first place, at the current project stage the humanitarian sector can benefit from a pilot stage development of the sustainable design-assistance tool, therefore enhancing its capacity with regards to sustainability. Additionally, the work tackles the challenge of developing a simple assessment method esponding to the contextual sustainability needs and priorities, and accounting for data scarcity and the complex diversity of the stakeholders globally involved in humanitarian construction projects. While the results still have to be considered as in-interim, the project shows the potential of proceeding in this direction, therefore handling the complexity of the sustainability discourse on the software side, while restituting to the user more digestible feedbck and recommendations.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest associated with the work presented in this paper.

DATA AVAILABILITY

Data on which this paper is based is available from the authors upon reasonable request. Specific construction project related technical data utilized in the project as baseline reference will not be distributed without prior ICRC approval.