Creating an assessment tool for environmental impact reduction of humanitarian shelters

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ABSTRACT:

Humanitarian organizations are increasingly concerned with reducing the environmental impact of shelter and settlement assistance. However, it remains challenging to assess environmental impact and circularity in practice to compare shelter performance and make pre- and post-construction choices. Until now there are multiple tools (being) developed focusing on reducing carbon emissions within the humanitarian aid sector. When taking into account the overall concept of sustainability, it is important to have a broad look onto environmental impact. Building upon life cycle assessment principles and the R-ladder for circularity strategies, we developed a novel decision-support tool.

By providing shelter materials and their weights, corresponding emissions and resource use are presented. The main results are shown as a conversion of the environmental impacts into euros which represent the summarized damage costs to the environment per shelter. For more detailed environmental impact data, 18 categories are defined using the ReCiPe 2016 methodology. We were able to show the impact ratio between the production phase of the shelter and the required transport of the shelter (materials), giving organizations a better insight where to focus on for reducing their environmental footprint. Next to that, a circularity core has been implemented for getting knowledge about circular performance and optimization strategies. This tool can help you to get insight in environmental performance beyond carbon emissions for making critical design and procurement choices. This is a first step towards environmental impact reduction of emergency shelter.

KEYWORDS:

Environmental Impact Assessment
Assessment Framework
Emergency Shelter
Life Cycle Analysis
Circularity

1. INTRODUCTION

Climate change is affecting planet Earth. The consequences of climate change are already visible because causes of climate change are not sufficiently mitigated. There are globally many political agreements to mitigate climate change, acknowledging its importance. The Paris Agreement aims to keep temperature rise below 2 degrees Celsius above the reference year 1990 (UNFCCC, 2015). One of the main measures is reducing carbon emissions by 43% by 2030 (UNFCCC, 2015). A way to reduce carbon emissions is through circular approaches, optimizing resource use and limiting waste (Yang et al, 2023).

Over 350 humanitarian organizations signed the "Climate and Environment Charter for humanitarian organizations," aligning their ambitions with the UN's Sustainable Development Goals (ICRC & IFRC, 2019). They advocate for environmental guidelines to reduce their carbon footprint in processes, products, and procurement (UNHCR, 2015, 2021). Emergency shelters play a significant role for the large amount of people in need of humanitarian assistance worldwide. The production and transport of these shelters towards the location of operation comes with resource depletion and environmental emissions.

Multiple organizations are busy with (development of) environmental analysis tools within the humanitarian aid sector. Amongst others there is the tool developed by EPFL in collaboration with UNHCR (UNHCR, 2023) and the tool of ICRC (ICRC, 2023). The tools so far are either focused on the analysis of greenhouse gas emissions and/or have a focus on a wide variety of goods.

In order to go one step further, this study aims to create an assessment framework which goes broader than greenhouse gas emissions. The purpose of the study is to create such an assessment framework (decision support tool) for emergency shelters.

The developed framework, which is partially LCA based, is giving insight in the environmental impacts of emergency shelters both on emission level and resource use and circularity level. This tool aims to support decision-making for pre-construction purposes, making conscious decisions in design, as well as post-construction decisions during procurement.

2. BACKGROUND & METHODS

This chapter describes background info that leads us to the chosen methodology and giving insight in the chosen methodology itself. The scope of the emergency shelter assessment tool is first described before elaborating about the methods we've implemented in the tool. This starts with the chosen environmental impact category methodology for being able to assess multiple environmental impacts, multiple ways (normalization) to be able to read the outcomes of the assessment more easily and the approach for circularity assessment of shelters.

2.1 Scope of the emergency shelter assessment tool

The aim of the emergency shelter assessment tool is to give insights in environmental performance during the design phase and procurement of shelters. The tool aims to offer the possibility to compare multiple shelters at once.

It is important to state clearly the decision framework mainly based on (part of) the production phase and transportation of the emergency shelter. This decision was taken to be able to assess the part of the life cycle which is fixed and to be able to assess the relativity of transport. The circularity section of the tool is also addressing criteria regarding the use and end-of-life phase of the shelter.

2.2 Environmental impact categories

Carbon emissions are very important, however, it does need to be emphasized carbon emissions are not the only environmental emissions that occur. When performing life cycle analysis (LCA) multiple life cycle impact assessment (LCIA) methods are available to express emissions and the use of resources into multiple environmental impact categories. In the world of LCA, ReCiPe, IPCC, ILCD and CML are common methods to express environmental impact.

This tool is an LCA based tool using the ReCiPe 2016 method to express the environmental effects of emergency shelters. ReCiPe 2016 is one of the most recent and most used methods (iPoint, 2018). This method differentiates 18 different environmental impact categories (midpoints). One of the impact categories is climate change, indicating carbon emissions, but other impact categories address freshwater consumption, ozone layer depletion, particulate matter formation and 13 more categories affecting human health, ecosystems or resource availability. The different impact categories are each as important as they are since no severity ratio has been defined for them.

Most of the categories are expressed in different units, making them unable to compare along each other. Due to this complexity, ReCiPe 2016 methodology includes a method of normalization which can more or less summarize the 18 impact categories into 3 endpoint areas of protection: 1) damage to human health, 2) damage to ecosystems and, 3) damage to resource availability.

Damage to human health is expressed in disability-adjusted life years (DALY), saying something about the quality of life and early life loss, while damage to ecosystems is an indication of biodiversity expressed as species loss integrated over time (species×year). The last category, damage to resource availability, is expressed in dollar ($). Applying this normalization is optional. It has the advantage of easier comparison of LCA outcomes, contrary the disadvantage is losing accuracy of the results. Figure 1 (RIVM, 2018) below shows environmental impact categories on midpoint level and how they contribute to certain environmental endpoint areas of protection.

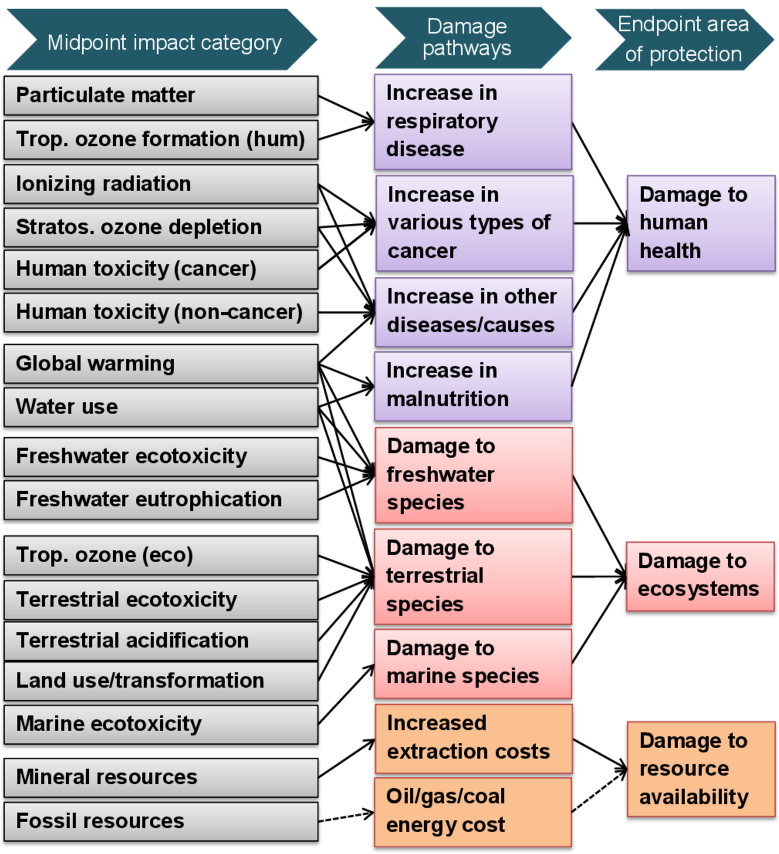

Figure 1: Relationship between environmental midpoint impact categories and environmental endpoint areas of protection (RIVM, 2018)

2.3 Environmental pricing

Even normalization towards the 3 endpoint areas of protection can still be complicated to interpret. Making the tool more user-friendly, another way of normalization is applied which is environmental pricing. Environmental pricing is a principle where the environmental damage is transformed into damage costs for different pollutive substances. The environmental damage costs are nowadays estimated and calculated for the environmental midpoint impact categories of ReCiPe 2016 LCIA method (CE Delft, 2023). Performing this normalization step makes it possible to compare the total environmental impact of a shelter based on one end score expressed in euros.

2.4 Circularity criteria

One of the most difficult aspects to quantify is circularity. Circularity, which is defined as a system where materials never become waste (Ellen MacArthur Foundation), is one of the concepts being a good measure against climate change and material scarcity. Then again, something circular does not have to be environmental friendly with regard to emissions, and vice versa. For example, if we are able to repurpose a product, that might be a circular approach, but if it comes with energy intensive processing it might not be the best solution. The other way around we might be able to come up with processing our product with lesser emissions but destroying the availability of our resources.

One of the frameworks forming a directive for end-of-life choices is the R-ladder as first thought of by the Ellen MacArthur Foundation (2015) and latest adapted by PBL, see figure 2. This directive describes the level of favorability of end-of-life choices where the higher the level of choice, the higher the circularity due to the lesser need for use of virgin materials. It is divided into the 10-R principle which are either assigned to smarter creation and use of products, extending the lifespan of products or make sure at least to give a useful application to end-of-life materials.

The R-ladder does provide directions for end-of-life strategies, but not in a quantified way. Since the decision framework is meant to assess earlier stages of the life cycle, circularity criteria applicable for shelter were selected from the circular economy toolkit (CircularEconomy Toolkit, 2013).

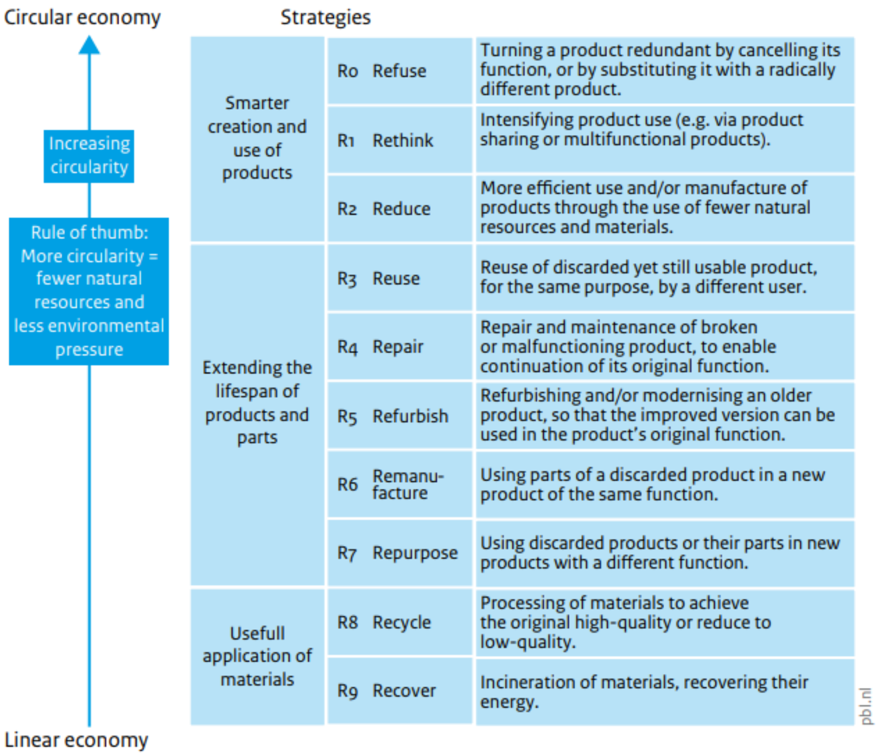

Figure 2: R-ladder as defined by RLi, 2015; adapted by PBL

3. RESULTS

The assessment approach was translated into a Microsoft Excel based assessment framework which will be described and shown in this chapter. The tool starts with a home tab containing some shortcuts to either start using the tool, going to an introduction tab on how to use the tool or getting background info about the used ReCiPe 2016 methodology. This chapter will describe the further setup of the tool, the shelter info fill in sheet and the dashboard showing the results

3.1 Shelter info fill in sheet

The tool is set-up to be able to compare a maximum of 3 (sets of) shelters at once. Therefore 3 identical shelter information fill in sheets are implemented in the tool. You can also just fill in the info for 1 or 2 shelters, up to the users preference. You have to provide info about the (raw) materials used for each shelter component, the frame, the tarp and the connectors (if applicable) and the type of processing that was done in order to turn the material into a shelter component. Figure 3 is showing the main part of the fill in sheet for 1 shelter (fictive data inserted).

Frame		**Weight**	
Material #1	Aluminium	100	kg
Processing #1	Extrusion (metal)		
Processing #2	None		
Material #2	Steel	200	kg
Processing #1	Casting (metal)		
Processing #2	None		

Tarp			
Material #1	PVC	75	kg
Processing #1	Extrusion (polymer)		
Processing #2	None		
Material #2	Polyamide (Nylon)	50	kg
Processing #1	Molding (polymer)		
Processing #2	None		

Connectors			
Material #1	Stainless steel	20	kg
Processing #1	Casting (metal)		
Processing #2	None		
Material #2	Aluminium	10	kg
Processing #1	Extrusion (metal)		
Processing #2	None		

Figure 3: Part of the shelter information fill in sheet, fictive data inserted

The second step is to provide transportation info for the shelter. First of all, the route of the shelter materials/components from the supplier to the stock location, second from stock location to port/airport of the project location and last from the port/airport of project location towards the final destination, the actual project location. It is not compulsory to fill in all these steps, you only have to fill in what you want to compare.

3.2 Dashboard

The dashboard is the outcome tab of the comparison tool. As it is not compulsory to fill in multiple shelters, the tool can also be used for comparison of the transport impact versus the production of the shelter impact. So the comparative purpose can be utilized in multiple ways. It is even possible to not use it for comparison purpose and just measure the impact of a certain shelter or of certain transport.

The main dashboard outcome figure is the environmental pricing, the environmental damage costs based on emissions and resource use of a shelter. Distinction is made between the transportation impact and the production impact (raw materials plus their processing) as shown in figure 4. Next to that, the impact per shelter is also shown expressed in person×year equivalent.

Environmental Pricing

	Shelter 1	Shelter 2	Shelter 3
Total	€ 618	€ 761	€ 1.564
Production	€ 532	€ 671	€ 938
Transportation	€ 85	€ 89	€ 626

Figure 4: Part of dashboard results, fictive shelter environmental pricing comparison

Below these most easy interpretable results, the impact of the shelters are shown on the ReCiPe 2016 environmental endpoint areas of protection level, damage to human health (DALY), damage to ecosystems (species×year) and damage to resource availability ($).

For more precise details on the environmental performance of the shelter, insights of environmental impact can be also derived on midpoint level where 18 different environmental effects can be consulted. Via a dropdown menu you are able to switch to either one of the 18 impacts of your preference.

Last part of the dashboard is containing a section with the focus on circularity aspects. As mentioned in the methodology chapter, the CircularEconomy Toolkit questions formed a basis for an assessment sheet. Multiple criteria, aspects were each assigned to the most relevant 'R' of the R-ladder. Questions can be answered with yes, no or not sure. The answer will be colored green in case of a circular answer, red in case of a non-circular or orange in case a not sure answer is given.

Criteria	Question	Shelter 1	Shelter 2	Shelter 3
Refuse new materials	Do you need a new shelter?	Not sure	Yes	Yes
Refuse new materials	Is there a shelter already in local storage?	Not sure	Yes	No
Redesign for circularity	Is there a high waste of materials during production?	No	No	No
Redesign for circularity	Does the shelter have biodegradable materials?	Not sure	No	No
Redesign for circularity	Does the shelter use scarce materials?	Yes	Yes	No
Reuse the shelter	Does the shelter have a longer lifetime than usephase?	Yes	Yes	Yes
Redesign for circularity	Does the shelter use toxic materials?	No	No	No

Figure 5: Part of dashboard results, fictive shelter comparison on circularity aspects (7 out of total 19 aspects)

4. DISCUSSION

The created Microsoft Excel based shelter assessment product is referred to as both a framework and a tool. Both terminologies are used in this study for a specific reason. With a framework is meant the basic structure underlying the actual assessment, while a tool actually implies a working concept. An important remark is that in order to use the created framework as an actual tool, material and processing emission data is required, at least for the environmental sustainability part of the tool. In many cases, such data is not available for free and needs to be paid for. In case you have access to the data, you could use the framework to fill it with the required data. The authors of this study have access to certain data and have implemented this in the framework, but it is not allowed to publish this. At the moment of writing, the search for free to use data is going on, hoping to be able to publish the tool in the near future. Until that time, at least the framework principle is set-up.

Due to insights that the tool is able to give, conscious design decisions can be made by shelter producers while organizations which are using shelters can make more critical decisions. It is up to the user to make a fair comparison in case of use for comparative purposes. For example, you could compare a shelter designed for 10 persons with a shelter designed for 20 persons, but in that case it is more logical to double the outcomes (or double the input) of the shelter designed for 10 persons.

The circularity questions section in the tool, derived from the CircularEconomy toolkit, are basically meant for awareness during the design and production phase and to prepare on end-of-life strategies and choices. The more green showing up, the better the circularity performance, also the higher (from top to bottom) the green is showing up, the better. There is no rule implemented for deciding which shelter performs better on specifically the circularity criteria, this is left to the users own conscious choice.

5. CONCLUSION

The goal of the study was to create an assessment framework for circularity and environmental sustainability of emergency shelters. Our framework combines circularity aspects and environmental emissions and use of resources by means of LCA principles.

The tool is mainly assessing the production phase of shelter(s) which includes the need of raw materials and the processing of these raw materials into actual shelter components. The possibility to compare multiple shelters and the option to see the relative impact of transport of shelters with regard to their production phase is also an extra strength of the tool. The circularity section of the tool is also addressing criteria regarding to the use and end-of-life phase of the shelter.

Via implemented automatic calculations and normalization of results, the tool should be able to support pre- and post-production decision making processes in a simple manner.

The first visible final result which is shown as environmental pricing in euros is a simplified way of comparison and is basically meant for comparative purposes only. For a more precise critical assessment of shelter impact it is recommended to look at the environmental impacts on environmental midpoint level.

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CONTRIBUTIONS

The study conception and design, funding acquisition, project administration, study supervision, methodology were performed by all authors.

The conceptual design of the tool was proposed by Alexander Compeer, building of the tool was done by Mitch Beveren, Damian van der Velden and Joran de Lange. The first draft of the manuscript was written by Alexander Compeer, co-authors gave their input during the development of the tool and helped improving the manuscript.

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