Initial Life Cycle Sustainability Assessment - Aligned general framework characteristics and selected Sustainability Indicators

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Description

Context

The aim of SP1.4 is to provide a tool to support an informed and holistic decision making for a sustainable decarbonization of the Swiss building stock. This Life-Cycle Sustainability Assessment-Framework (LCSA-F) tool aims at integrating four methodologies, which are Environmental Life Cycle Assessment (eLCA), Social Life Cycle Assessment (sLCA), Life Cycle Costing (LCC) and Resilience Assessment (RA) under the overarching Multi-Criteria Decision Analysis (MCDA) methodology.

MCDA will allow stakeholders to compare different potential renovation measures (alternatives) with respect to the current state of the building under interest by means of providing ranking and scores of each alternative and their sensitivity to the weighting profile provided by the users. Therefore, the proposed tool makes use of one of the main family of MCDA methods, which is represented by composite indicators (CIs), or indices, since it leads to a score of the alternatives that can then be easily ranked (Greco et al., 2019). The initial development of the proposed framework consists in:

- the definition of the system boundaries;
- the definition of the criteria and subcriteria describing the eLCA, LCC, sLCA and RA domains;
- the weighting of the criteria;
- the selection of the MCDA method to be implemented in the tool.

Initial Framework Development

The initial development of the proposed framework was achieved in close collaboration with a group of eight experts from academia, construction enterprises, consulting, etc., to grasp the heterogeneous knowledges and interests from these different domains. Particularly, the experts participated to two workshops to help defining the proposed framework.

In the 1st workshop the experts were asked to define the system boundaries of the framework and their level of details. In this context, the group uniformly voted for covering the whole life cycle including the product stage, the construction process stage, the use stage, and the end-of-life stage as well as presenting all results at the process stage level. Furthermore, the experts voted the functional unit (FU) for the LCSA framework, which results to be “heated area per year of building lifetime” due to its wide application in the Swiss building context expressing the building’s energy demand.

Moreover, during the 1st workshop, the group of experts selected the criteria to be included in the framework, since CIs are based on an aggregation of criteria that measure different domains. In this context, the framework presented here is based on a hierarchical structure of the criteria, which is composed by 3 layers (Figure 1).

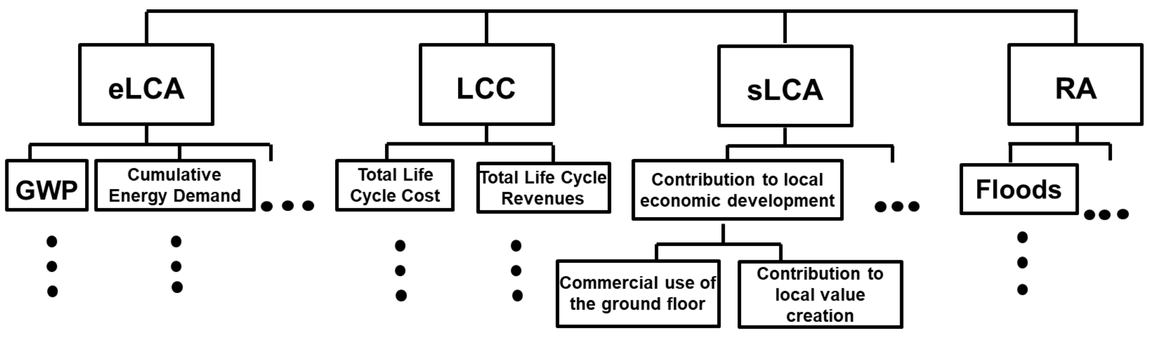

Figure 1: Hierarchical structure of the proposed framework.

In the first layer the four abovementioned domains, i.e., eLCA, LCC, sLCA, RA, are present. The second layer is composed by a set of 16 criteria, subdivided into 5 for eLCA and sLCA, 4 for RA and 2 for LCC, which were defined based on a comprehensive literature review and the expert selection during the 1st Workshop. The 3rd layer of the hierarchical structure of the framework contains a set of 56 subcriteria, subdivided into 10 for eLCA and sLCA, 9 for LCC and 27 for RA, which were selected based on a comprehensive literature review and in accordance with the group of experts.

Once the criteria hierarchical structure of the LCSA-Framework was defined, during the 2nd Workshop, the experts were asked to weight the 2nd and 3rd level of the hierarchy to build a default preference profile, different to the equal weights one, to be included in the tool under development (Table 1).

Table 1: Hierarchical Structure of the LSCA-F and relative expert related weight profile defined in this study.

Domain	**eLCA**									
Criteria	Global Warming Potential			Cumulative Energy Demand		Land and water (ecosystem) impacts		Atmospheric impacts (ozone)		Abiotic Depletion Potential
Weight [%]	24%			22%		20%		18%		16%
Sub-criteria	GWP100-fossil (CO_2-eq.)	GWP100-biogenic (CO_2-eq.)	GWP100-land transform-ation (CO_2-eq.)	Non-renewable CED (MJ)	Renewable CED (MJ)	Acidi-fication (AP) (kg SO2 eq)	Eutro-phication (EP) (kg PO4-- eq.)	Stratospheric Ozone Depletion Potential (ODP) (kg CFC-11 eq)	Photo-chemical Ozone Creation Potential (POCP) (kg NMVOC)	Abiotic depletion,el ements (kg Sb-eq.)
Weight [%]	39%	32%	29%	54%	46%	54%	46%	51%	49%	100%

Domain	**LCC**								
Criteria	Total Life Cycle Cost					Total Life Cycle Revenues			
Weight [%]	57%					43%			
Sub-criteria	CAPEX	OPEX	CO_2 fee	Disposal fee	Taxes	Material sales	Energy sales	Rental income	Subsidies
Weight [%]	24%	24%	20%	18%	15%	23%	25%	30%	22%

Domain	**sLCA**									
Criteria	Save and healthy living conditions for users			Accessi-bility for all kind of users	Contribution to local economic development		Cultural heritage of building/district		Promoting social responsibility	
Weight [%]	29%			20%	15%		17%		19%	
Sub-criteria	Acoustic/th ermal comfort	Indoor air quality: VOC concen-tration	Possibility for users to exert influence	Accessi-bility of the building for all user groups	Commercial use of the ground floor	Contri-bution to local value creation	External appearance and image/ spreading effect in the neighbour-hood	Possibilities for traditional, social activities in the buildings /settlements	Fair wages in value chain	Environ-mental standards in value chain
Weight [%]	36%	36%	28%	100%	46%	54%	45%	55%	49%	51%

Domain	**RA**												
Criteria	Floods							Heavy Rain / Hail					
Weight [%]	23%							25%					
Sub-criteria	Plinth Level	Drainage	Floor Covering	Wall Material	Wall Thickness	Resource Avail-ability	Personal in Place	Doors Material	Wall Material	Floor Covering	Windows Type	Resource Avail-ability	Personal in Place
Weight [%]	19%	18%	16%	15%	11%	10%	11%	10%	19%	13%	17%	17%	12%

Criteria	Heat- & Coldwaves						Blackout / Energy Shortages						
Weight [%]	29%						22%						
Sub-criteria	Thermally Active Building System	Thermally Loadable Air Supply Systems	Wall Thickness	Wall Material	Insulation and Light-surface (Albedo)	Expected Adverse Thermal Conditions (days)	Electricity Autarchy level	Backup for electricity	Backup for water	Backup for heating	Wall Thick-ness	Wall Material	Insulation and Light-surface (Albedo)	Expected Blackout Shortage (Days)
Weight [%]	20%	15%	19%	18%	17%	11%	17%	16%	14%	11%	8%	7%	7%	10%

Finally, based on the problem type, the criteria and subcriteria nature, the preference elicitation, and the features of aggregation under interest, the most reasonable MCDA method for the tool under development was selected. In this context, the Multi-Attribute Value Theory (MAVT) was found to be the best methodological solution based on the MCDA-MSS tool, which is available on http://mcdamss.com (Cinelli et al., 2020).

Added-Value

The tool proposed in SP1.4 is a first-of-its-type framework, which combine the sustainability and resilience domains in the context of decarbonization through renovation of existing buildings. Particularly, the tool will allow stakeholders, users, etc. to give their preferences (weights) to the most important criteria for them as well as to iteratively assess the scores/ranking of the renovation measures (alternatives). The latter will help the stakeholder/users for an informed decision-making process to find the most sustainable renovation solution for the multi-family house under interest.

Challenges

During the initial development of the framework, different challenges were encountered, as summarised in the followings:

- Although a heterogeneous group of experts was built, it took quite some time to be able to get a sound number of experts able to get involved in the workshops.
- Defining a sound set of case studies as well as the renovation measures as alternatives are still a challenge, which will be solved in the next few months.

References

Greco S, Ishizaka A, Tasiou M, Torrisi G (2019) On the methodological framework of composite indices: a review of the issues of weighting, aggregation, and robustness. Social Indicators Research 141:61–94, doi: https://doi.org/10.1007/s11205-017-1832-9
Cinelli M, Kadzinski M, Gonzalez M, Slowinski R (2020). How to support the application of multiple criteria decision analysis? Let us start with a comprehensive taxonomy. Omega, 96, doi: https://doi.org/10.1016/j.omega.2020.102261