Temporary housing environments in urban areas – challenges and key findings for implementation

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Abstract. Cities are increasingly confronted with the need to provide short-term and cost-efficient housing as several factors, such as natural disasters, migration due to political or climatic circumstances or other unpredictable events can result in a sudden and at times temporary need for additional housing. Providing affordable, and flexible but at the same time sustainable and re-useable housing concepts that are easy to construct and quickly to implement are thus requirements that cities must face. Currently there is limited research available in this field, as disaster architecture and temporary housing have not yet been widely researched in an interdisciplinary manner. The project "Urban pop-up housing environments and their potential as local innovation systems" has aimed at addressing this research gap by investigating in a highly interdisciplinary approach how and under which circumstances temporary housing solutions could be implemented under challenging framework conditions. The aim of the project was to systematically investigate and evaluate existing temporary housing options, and to develop and assess innovative and sustainable models for pop-up living systems in urban environments regarding resource uptake as well as social aspects, which may serve as incubators for urban innovation. From a technical perspective the models are focused on integrating aspects related to architecture, energy technologies, resources and materials, water as well as landscape design. Starting with a data pool of international examples, a classification and systematization of relevant typologies has been carried out in combination with user profiles for the different housing situations. On this basis, potential urban areas have been identified for selected scenarios and finally six theoretical temporary housing models have been created and subsequently assessed and analyzed in detail. The purpose of this paper is to present the key findings related to the scenarios and models, that have been developed within this basic research project and the methodologies that have been applied to assess them. The challenges of the scenarios and overall project results are summarized to provide an outline for potential implementation and future pilot projects.

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1 Introduction

Cities increasingly need to provide high quality living environments for their inhabitants whilst at the same time also considering that a rise in population does still ensure a transition towards a resilient and sustainable urban system. Providing adequate and affordable housing is a key topic and challenge against the backdrop of population growth, however it is also a driver for energy and resource needs. Permanent housing structures are the backbone of every city to ensure a lasting and well-established infrastructure. However temporary housing can address certain needs that arise out of urgency or an unforeseen demand. Thus, temporary housing is associated with a multitude of facets: these building typologies become more widely recognized as cities are faced with heterogeneous and interlinking challenges such as migration, densification, climate change and the requirement to provide high quality living environments for their permanent or temporary residents.

Several examples highlight the importance of this typology for short-term living accommodation after disasters or for imminent migration needs. Case studies in Sweden [1] and Italy [2] outline approaches and strategies in this respect. Making the transition from the temporary to the permanent for the inhabitants is in this context a crucial aspect as a return to their original habitat is often not (immediately) possible for people who have moved to temporary shelter [3]. Other relevant applications address the experimentation with cultural activities [4] or the use of temporary vacant urban plots for the application of processes in a cultural context [5]. These creative applications of urban space or temporarily unused buildings have been extensively covered in one of the research papers that resulted from the here discussed project [6]. In other urban examples, temporary housing is faced with profitability issues, thus moving away from typologies that are urgently needed for a particular user group towards typologies that are wanted as part of urban densification [7].

Whilst the temporary aspect can be both positive and negative from a social perspective, the same applies for the ecological sustainability. Whilst "temporary" often means that there is no foundation and thus no sealing of urban surfaces or that re-usable structures are used, it can also mean that buildings are of low quality as they are not built to last. Structures that are not built for permanence are thus not per se sustainable as the framework conditions related to e.g., material, fabrication, construction, and re-use must be considered to assess the environmental impact. Life Cycle Assessments (LCAs) are applied in this respect also for temporary housing [8] to analyse the sustainability of temporary buildings. Building deconstruction as a fundamental strategy is thus highly relevant as resources can be more extensively used when components and whole buildings are re-used. Temporary structures can in this context serve as examples and prototypes for larger scale-up [9]. In addition to the impact of the material and construction, the impact during operation must be considered as these building types also need energy and resources in use. Assessments in this respect have been published regarding disaster building types [10]. However, there is still a need to comprehensively assess these temporary structures to provide factual decision support for urban development scenarios related to design type, site selection and cost [11].

In the research project "Urban pop-up housing environments and their potential as local innovation systems" [12, 13] an inter- and transdisciplinary approach has been used to systematically investigate and evaluate existing temporary housing options and to create integrative, innovative, and sustainable models for pop-up living systems in urban environments. The core objective of the project was to develop a sound interdisciplinary scientific basis for temporary housing for diverse scenarios such as selected target groups, different temporarily unused as well as vacant urban areas and diverse building densities in the Viennese context. Within the project, several research groups from the field of water and sanitary engineering, energy engineering, waste management, architecture and urban planning, spatial planning, landscape planning and social sciences worked together within a highly interdisciplinary setting to define sustainable, low-impact scenarios and housing

models. In the context of the project, "temporary" refers to a duration span of several weeks up to five years. The structures are considered temporary in terms of their use as a living space and the re-purposing of permanent structures for temporary residential use. The relevance for the City of Vienna relates to the diversity of user groups with a need for temporary housing that already exists or that can be expected in the near future thus considering both the scope in terms of number of people and the relevant urgency from the individuals seeking shelter. From an urban planning perspective, the availability of adequate areas or vacancies within the city and the likelihood of decisive or disastrous events, such as heatwaves, earthquakes, energy disruption or sudden increase in numbers of asylum seekers is considered as a relevant prerequisite.

The above-described project has aimed at addressing several aspects related to temporary housing, one of which is focusing on the overall sustainability of these structures. The aspects of temporary forms of housing are being analysed from different angles including energy technology, architecture, circular economy, landscape planning, spatial planning, risk assessment, waste, and wastewater management as well as technology assessment and social sciences. Due to the lack of disciplinary methods that cover all these areas in an integral approach and the lack of possibilities to make important aspects of the different considerations understandable to every discipline in a clear and simple way, a specific, tailor-made assessment methodology has been developed to address this gap.

This paper provides an overview and partly summary of the approach and methodology for the sustainability assessment of temporary building types that has been developed within an interdisciplinary team as part of the research project "Urban pop-up housing environments and their potential as local innovation systems". The paper is based on the key results that have been outlined in the final reports of the research project [12, 13].

2 Methodology sustainability assessment

The goal of the methodological development was on the sustainability assessment of temporary housing models for different applications under the same framework conditions. In the area of interdisciplinary and transdisciplinary research a multitude of subjects, sectors and topics should be addressed ideally within a single approach, which is a challenging task, given the multitude of methodological approaches and methods of measurement and evaluation the various disciplines are working with. Within the context of the research project, the focus to assess the sustainability of temporary housing solutions was set on the ecological, technical, site-related and social aspects. Encompassing this wide range, research effectiveness can be limited by difficulties in the interplay of these varied aspects. The development has been carried out in a three-step approach starting with the (1) definition of goals and evaluation criteria, followed by the (2) definition of specific indicators and the (3) definition of the overall evaluation system as outlined in Fig. 1.
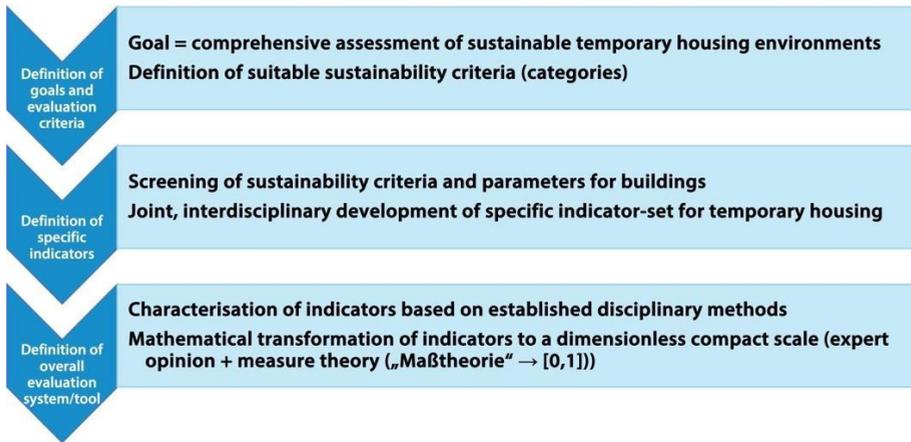
Fig. 1. Approach for the methodology for the assessment of the sustainability of temporary housing models [12,13].

To cover and include all relevant aspects from the various scientific fields, the incorporation of a formal structure has been necessary as an initial step in the development of the methodology. For clarity and structure, four general areas were derived and determined to serve as 'indicator quality groups', these include (1) Ecological Quality, (2) Technical Quality, (3) Site Quality and (4) Social and Residential Quality (Table 1). Within these four groups, aspects that have been determined relevant related to sustainability assessments for temporary housing structures have been included.

Table 1. Key aspects in indicator quality groups for the sustainability assessment of temporary housing environments [based on 12,13].

Ecological Quality [13 Indicators]	Technical Quality [15 Indicators]	Site Quality [11 Indicators]	Social and Residential Quality [12 Indicators]
Utilization of resources	Energy consumption	Sustainable land use	Health and well-being
Emission-related environmental effects	Material cycle	Mobility and access to services	Functionality
	Comfort	Image and condition	
	Operation		

To enable a justifiable and balanced assessment, an evaluation system algorithm has been developed. The strategy was, to find a common value space for the different partial aspects. Due to the inter- and transdisciplinary variety, it has been a challenging task to define suitable value spaces, i.e., solution strategies that satisfy all the contributing disciplines. In addition to very different terminologies, which are used by each of the respective disciplines, one can easily reach a conflict when evaluating different approaches, as, for example, a solution approach might work very well for one specific discipline but might not be acceptable for another one. Also, the same terms are sometimes used for different meanings in different disciplines. For example, the term 'Impact' usually has a negative connotation from an ecological perspective but can be associated with a positive meaning from a social point of

view. For the methodology, the proposed value space has been developed to cover all aspects, so-called qualities, considering the definition of acceptance-mapping. Regarding individual indicators, suitable disciplinary evaluation approaches already exist. However, these differ greatly in the choice of the evaluation space and the choice of a proper set of values. These differences made it difficult to find an evaluative comparison between individual indicators that considers very different aspects fairly and comprehensibly. The goal was therefore to define an evaluation space that could be applied to each indicator with a generally understandable set of values. Also, a key aim was to apply a practicable method that can accompany the process of a sustainability assessment within a planning process. With this approach it has been possible to use existing evaluation methods for the various disciplines and to map them in the common value space. This approach greatly simplified the collaboration between the various disciplines and made it easier to identify any conflicting aspects that might arise.

Within the four quality groups, a series of indicators has been defined, with the objective to render these indicators comparable. The objectives of the development of the indicators was focused on four key characteristics: (1) Equality of the individual indicators (comparability); (2) Evaluation via expert methods or expert assessment; (3) Standardized representation and (4) Comprehensibility and traceability without expert knowledge. For each indicator a measure in the sense of an acceptance measure has been developed. This measure reflects the expert's assessment about the quality of the fulfilment for the respective indicator.

In the following an overview of the indicators of the four 'indicator quality groups', totalling in 51 individual indicators is given:

Ecological quality (Table 2): The first indicator quality group deals with all relevant aspects related to environmental consequences of the build, operation / use, and deconstruction of the temporary housing model, covering aspects such as Global Warming Potential (GWP) and emissions of CO_2 equivalent. during the whole life cycle of a specific temporary housing model. The key parameters are mainly taken from well-known LCA guidelines and standards.

Table 2. Overview and abbreviations of Ecological Indicators [based on 12,13].

No.	Abbreviation	Indicator
1	GWP_MEPP	GWP material extraction and production phase
2	GWP_EC	GWP construction phase
3	GWP_OMP	GWP operational phase and maintenance
4	GWP_DP	GWP deconstruction phase
5	GWP_EOL	GWP end of Life phase
6	GWP_T	GWP emissions Total
7	W_Ru	Water reuse
8	PED_O	Primary energy demand – operation
9	W_Fp	Full water footprint
10	WP_FP	Product water footprint of materials used in building
11	WU_DO	Water use during operation
12	WU_CD	Water use during construction and disassembly
13	S_UF	Stock usage factor

Technical quality (Table 3): The second indicator quality group addresses building-relevant technical aspects such as energy (consumption) figures (e.g., heating, domestic hot water, cooling, primary energy demand), the degree of building automation, the ease of (dis-)assembly and maintenance and other parameters which significantly influence the overall

operational quality of the building. Energy parameters are mainly taken from existing energy guidelines and standards and are being calculated accordingly.

Site quality (Table 4): The third indicator quality group includes parameters like the suitability of a site and the suitability for a specific building use. Parameters like ecologically sensitive areas on site are also included. Various inputs derive from the theory of open space planning as well as basic data from publications by the City of Vienna and relevant gender mainstreaming in urban planning and urban development strategies.

Social and Residential Quality Indicators (Table 5): The fourth indicator quality group refers to indicators related to the quality of life that is facilitated by the organizational, built- and spatial structures of the building and open spaces on the plot. The indicators were developed within an interdisciplinary approach by social scientists together with landscape planners and gender and diversity specialists.

Table 3. Overview and abbreviations of Technical Indicators [based on 12,13].

Nr.	Abbreviation	Indicator
1	C_{ED}	Energy demand- cooling
2	$C_{renewe,E}$	Coverage energy, electrical
3	DLQ	Daylight quality
4	SEP_{renewe}	Share of Energy Production Renewable
5	HED	Energy demand - heating
6	L_{ass}	Level of ease of assembly
7	B_A	Level of building control
8	MB	Maintenance building structure
9	MB_{ES}	Maintenance building engineering Services
10	R_P	Recycling potential
11	D_{reuse}	Reuse potential (end of life)
12	L_{disass}	Level of ease of disassembly
13	SM_U	Secondary material utilization
14	MCI	Material circularity indicator
15	R_R	Realizable recycling factor

Table 4. Overview and abbreviations of Site Quality Indicators [based on 12,13].

Nr.	Abbreviation	Indicator
1	CT_P	Connection to public transport
2	AM_P	Active mobility on the plot
3	AM_Q	Active mobility in the quarter
4	P_{OF}	Proximity to use-specific objects and facilities
5	POS_{QC}	Access to public open spaces in the district and city
6	GI_P	Green Infrastructure on the Plot
7	A_{ADO}	Accessibility for assembly, dismantling and operating phase
8	SR_{AN}	Suitability for residential use depending on ambient noise
9	L_{UE}	Land use efficiency
10	S_{Site}	Suitability of site
11	C_{ES}	Consumption of ecologically sensitive areas

Table 5. Overview and abbreviations of Social and Residential Quality Indicators [based on 12,13].

Nr.	Abbreviation	Indicator
1	Ea_{P_P}	Effective area per person
2	F_C	Facility category
3	Ea_{P_C}	Effective area per person (Community)
4	S_{CC}	Spaces conducive to communication
5	BF_{AR}	Barrier-free accessible rooms
6	C_{SL}	Changeability of the room size and layout
7	GD_A	Gender+ and diversity aspects of built and open space structures on the plot
8	P_R	Empowerment & type of participation
9	OS_P	Private open spaces
10	OS_C	Communal open spaces
11	AMU_P	Open spaces of areas with mixed use
12	RQ_d	High residential quality in the district

The methodology and key results are based on the publications resulting from the research project [12, 13]. The overall methodology and detailed mathematical approach used to numerically describe the indicators has been published as part of the research project [14].

3 Results sustainability assessment

The above-described methodology has been iteratively adapted and tested using the six temporary housing models, which have been developed as theoretical case studies as part of the research project. The models show in general a high level of diversity to demonstrate the quality of the assessment method.

To illustrate the application of the methodology within the context of this paper, the results of the sustainability assessment for two examples out of the six developed housing models are described and summarized. Figures 2 and 4 show the designs for the exemplary housing models, figures 3 and 5 show the visualization of the interdisciplinary assessment using the developed housing model as case studies. All 51 indicators were normalized and scaled between 0 (low quality) and 1 (high quality) and grouped into the four indicator quality groups: ecological quality, technical quality, site quality and social and residential quality. The closer the indicator reaches "1", the higher the quality. For the overall plot it means, that if a larger area of the plot is covered, the higher the quality (respectively the sustainability) in these four categories. In general, it must be noted that the design of the housing models was developed within the Viennese context and the associated high housing standards. Thus, the requirements for the housing quality were already a priori very high, which in turn resulted in a higher technical and a more complex configuration. This is reflected in the evaluation in the partly quite low ratings of some of the technical and ecological indicators.

The symbols/ abbreviations of the indicators used in the plots can be found in the list of symbols as outlined in Tables 2 to 5.

Scenario 1: Beat the Heat (Fig. 2): In the first exemplary scenario temporary spaces for the use during heat waves are considered. As central European cities such as Vienna are increasingly faced with high summertime temperatures and subsequent heat island effects in dense urban areas, vulnerable groups that live in buildings that cannot adequately cool down during summer overheating could face an increased health risk. Thus, in this example, temporary housing is planned primarily for the duration of heatwaves by temporarily setting up de-constructible environments in cooler areas of the city.

Fig. 2. Rendering of the design for exemplary housing model and scenario 1 [12,13].

Fig. 3 shows the visualization of the interdisciplinary assessment in four assessment plots using this housing model within the scenario "beat the heat" as a case study. As noted above, the design already included a very high quality of housing standard requiring a high level of technical systems. This is subsequently reflected in the evaluation in the partly quite low ratings of some of the technical and ecological indicators. However, this model can be constructed and dismantled easily and quickly (indicators level of ease of assembly/disassembly) but it was assumed that the exterior spaces would need to be extensively adapted to ensure a high living quality, which resulted in the low values in the site related parameters.
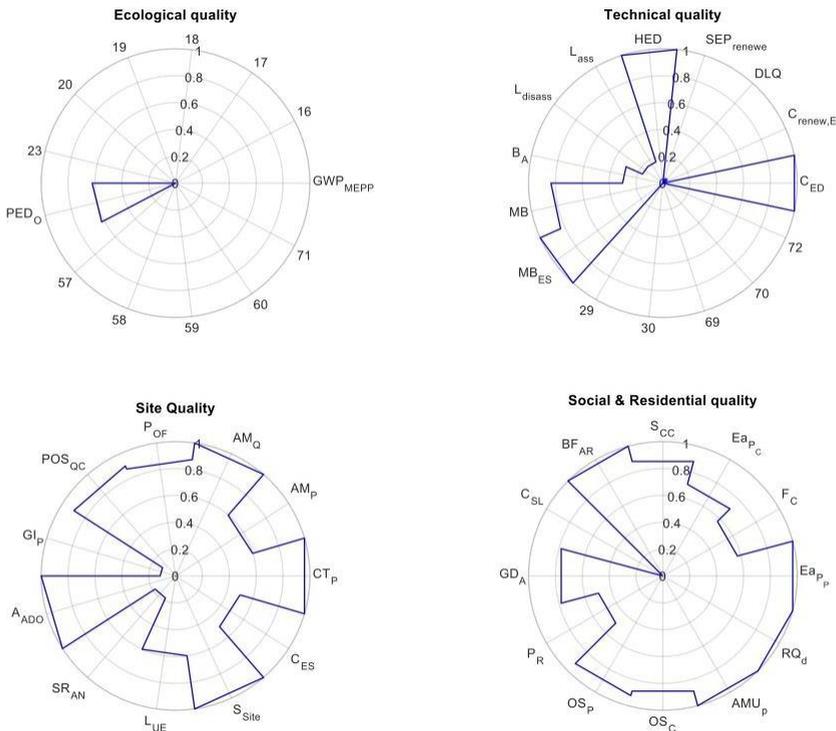

Fig. 3. Exemplary assessment plots for the housing model 1 (Scenario "Beat the Heat") [12,13].

Scenario 2: Gap Module (Fig. 4): In the second exemplary scenario vacant building lots within dense urban areas, that are temporarily empty are considered for short-term accommodation between two and five years. These potential plots would need to be at least 1000m^2 in usable area to construct and operate multi-storey temporay buildings that are prefabricated and that can be constructed and de-constructed within a short timeframe. The focus for this example is on easily accessible plots that have a good connection to urban infrastructure and that can be used for a limited time.

Fig. 4. Rendering of the design for exemplary housing model and scenario 2 [12,13].

Fig. 5 shows the visualization of the interdisciplinary assessment using the housing model for scenario 2 as the theoretical case study. Similarly to the above example, for this housing model, the housing quality was given a high priority, which required a higher technical and a more complex configuration. This is reflected in the evaluation in the partly quite low ratings of some of the technical and ecological indicators. Moreover, the model assumptions for the site quality were selected as very appropriate, resulting in a very high score for these indicators.
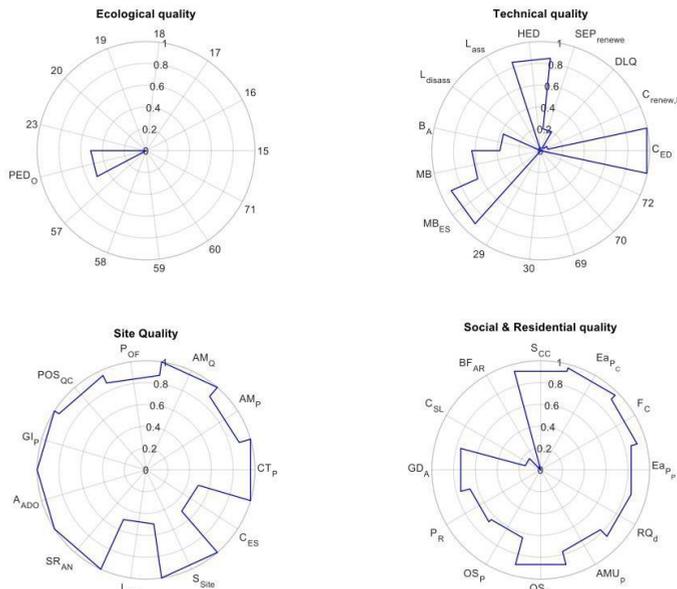

Fig. 5. Exemplary assessment plots for the housing model 2 (Scenario "Gap Module") [12,13].

4 Conclusions

There are a multitude of influencing factors that limit or foster the development and subsequent implementation of temporary housing within the urban environment of a city. The temporary housing models developed as part of the described project show some potential solutions for flexible, sustainable, and reusable concepts, that are easy to construct and swift to implement, to fulfil the requirements of environmental and social sustainability. Including temporary uses and applications in urban planning strategies can subsequently provide readily accessible measures when they are urgently needed.

For the sustainability evaluation and a comparison of different housing models and scenarios, an interdisciplinary assessment method was needed. Due to the lack of suitable existing methods, a new methodological approach for the evaluation of sustainability related to ecological, technical, site-related, and social aspects has been developed. Within the framework of the discussed project, it has been important to find a quantitative method, which not only allows an evaluation, but also accompanies and supports the interdisciplinary cooperation in general. The core of the developed methodology is the set of 51 indicators that are grouped according to the four indicator quality groups. The indicator set has been assessed in a first step using temporary housing models as theoretical case studies.

Overall, the results show that the developed indicators and methodology can serve as an adequate, basic assessment approach for the sustainability evaluation and refinement of temporary housing options regarding ecological, technical, site-related, and social aspects. The assessment plots, which result from the detailed analysis of the 51 indicators, provide a sound overview and comparison of different temporary housing examples. The graphical representation can support the facilitation of discussions within diverse stakeholder groups and can thus help to make informed decisions for the adequate design for a particular application and urban scenario.

However, there are several limitations, that need to be considered when applying the developed approach: Even though the methodology has been tested for the theoretical temporary housing types, a more in-depth sensitivity analysis would need to be carried out to analyse the scaling for each indicator, and the derivation and abstraction of general principles and interrelations between the assessment indicators. For example, the investigation of the tolerance limits of the individual indicators as well as the analysis of the dependencies and influences among each indicator requires further evaluation and subsequently validation.

Nevertheless, the methodology can provide an initial indication and is unique in a sense that it combines in an interdisciplinary approach within one common tool a quantitative assessment from various disciplines.

Acknowledgments

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