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Research Article

Applying design science approach to architectural design development

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Abstract Unlike research methods for social and positivist sciences, those for architectural design lack a discipline-specific conceptual framework. Performative science aims at producing outcomes for future use and therefore needs a robust methodological approach that encompasses different techniques and methods supporting an evidence-based architectural design development. This study suggests that design science can be successfully applied to architectural design development and provides architects and designers with a powerful tool bridging the gap between research and design. In so doing, this study explores the application of design science to implement a user-centered design approach. A design challenge is reframed within the robust framework of design science by referring to a case study on refugee shelters. The traditional method by which shelter optimization is pursued by designers is questioned by involving the final users through an ethnographic approach within the framework of design science. The design outcome produced through this process is a list of specifications allowing designers to create different architectural solutions and matching the requirements expressed by future users. The authors argue that a user-centered design outcome can be achieved and validated through design science.

1. Introduction

Architectural development has been often considered a peculiar research path because of the exploratory and iterative nature of the design process, although "the debate about the equivalence … between research and design is often contentious and complicated" (Groat and Wang, 2013: 23). Architectural design is a complex process in which scientific and social matters must be combined and balanced to obtain a sound response that can address users' needs. The social–constructivist epistemological stance is paramount when cocreating an architectural response to a given matter by ensuring that the design

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outcome really addresses what the users' needs are. However, the postpositivist rigorous testing of expected outcomes against a given set of data is equally essential. "Design can be conducted within a postpositivist understanding of knowledge (i.e., usually assumed to reflect the 'scientific' method), and research can and does occur within non-'scientific' epistemologies, including what is often referred to as constructivist or subjectivist perspectives" (Groat and Wang, 2013: 24). Such a complexity of instances can only be grasped by a mixed-method approach. However, a robust iterative research framework tailored on the peculiarity of architectural design is also useful and supports the reliability of the architectural research field as a "scientific" discipline. This research is conducted by relying on the design science framework and combining scientific and "nonscientific" approaches in consistency with the nature of the architectural field. As highlighted by Cross (2006: 98), "design science refers to an explicitly organised, rational and wholly systematic approach to design; not just the utilisation of scientific knowledge of *artefacts*, but design in some sense a scientific activity itself".

This study suggests that design science can be implemented within the architectural design process rationale to create a robust framework for producing design outcomes, given it can compose a multiple iteration position of its phases, namely, explicating the problem, outlining the requirements, developing a new artifact, demonstrating the artifact, and evaluating the artifact by contextual knowledge resulting from the research to understand the world. To the best of the authors' knowledge, this study is the first attempt to apply the design science methodology to the production of an architectural artifact. A single case study strategy is selected to prove the effectiveness of this approach. The researchers focus on the architectural design process of a refugee shelter. The current approach to the design of refugee shelters is questioned with data collected from the Al Za'atari Camp in the north of Jordan in relationship with the refugees' needs. According to empirical research and previous studies on refugees' situation in camps, the current shelter design does not fully meet the users' needs. Hence, the design methodology implemented by the researchers is aimed at filling the gaps in the design by developing a framework that incorporates the users' needs within a solution of general interest, as in the purposes of design science. An ethnographic approach is selected to achieve a thorough understanding of the users' views of shelters. The suggested methodology is implemented first to create a list of specifications that is useful to steer the design process and then test it through the actual design of shelters performed by a group of designers and architects. The list of specifications is created and tested by the stakeholders (refugees, experts, researchers, local government, and NGOs) through an iterative process. The original contribution of this study to architectural design methods belongs to the field of design methodology. This study demonstrates how design science may help restructure traditional architectural design methods and articulate their sequence within a robust framework; moreover, it overcomes the ambiguity that still persists in architectural design methodologies, which are suspended between postpositivist and "nonscientific" epistemologies. The study also shows how design science can help reconcile a user-centered approach with an approach based on a "scientific" evaluation of the design. Design science is based on an iterative approach, which allows designers to rely on multiple approaches, including incorporating end-users' and stakeholders' perspectives. This study concludes that design science can be considered a novel framework for supporting the articulation of a scientifically sound architectural design strategy.

2. Design science and the architectural design process

2.1. Design science and the creation of novel design solutions: artifact versus project

Design science, which innovates by creating something new (artifact) of general and unspecific interest, is a new area in information system (IS). Grand and Jonas (2012) stated that design science started in the 1960s, when scientists were beginning to produce the process of rationality by design process. In 1920, architects and engineers were supporting design as an objective way to show productive knowledge, such as the project "machine for living" by Le Corbusier.

Hevner and Chatterjee (2010) argued that design science activities within IS work describe data under a conceptual framework of IS, as shown in Fig. 1. Saunders, Lewis and Thornhill (2009) mentioned that the aim of design science is to develop an artifact using valid knowledge to support problem solving in a certain context, whether directly, such as via a model, or indirectly, such as giving an instruction; in this regard, design science is a solution oriented in considering human activities.

Lukka (2003) indicated that the design science method aims to support a constructive innovation that solves a problem in the real world, where the contribution of theory exists through the discipline of application. Multiple research processes are required in design science phases. Many empirical research methods describe, explain, and predict the world and aim to explain phenomena regardless of human activities, whereas design science goes further by seeking change, improvement, and the creation of new worlds in the form of methods, models, ideas, systems, and specifications (Vaishnavi and William kuechler, 2007). Natural science is a form of knowledge on objects or phenomena regardless of society; it describes how things interact while developing a novel idea. This knowledge form takes the common processes of research, including problem definition, literature review, hypothesis development, data collection, analysis, and results. Artificial science (design science) is a form of knowledge related to the design of artificial (man-made) objects or phenomena, targeting specific goals and using the design solution to solve problems of complex context (Hanid, 2014). Social science research describes a phenomenon and the behavior of such phenomenon to solve a problem, whereas design science creates a blueprint by developing an artifact to solve a problem.

Vaishnavi and William kuechler (2007) indicated that the awareness of a problem comes from different sources, which might deliver a new definition in the field and

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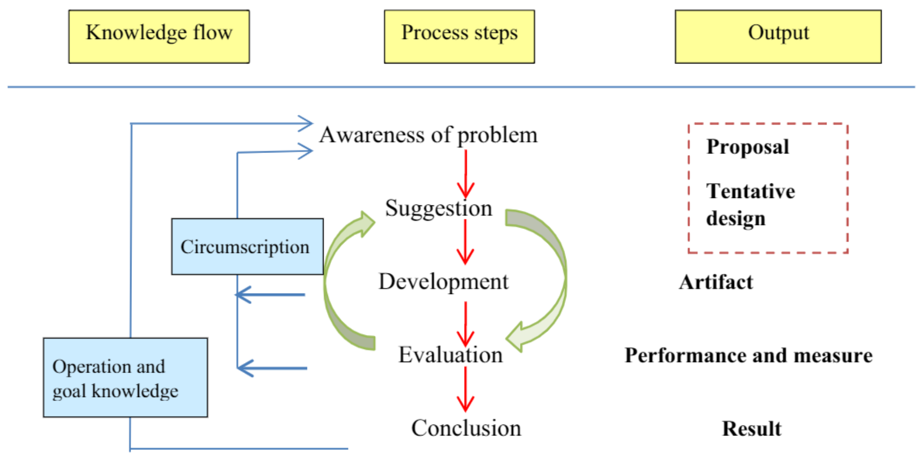

Fig. 1 General methodology for design science research (Source: Vaishnavi and William kuechler, 2007, p. 20, p. 20).

formulate a proposal of the output. A suggestion follows, resulting in a tentative design. Other research models might propose a design; however, such models are only a part of the design proposal. Design science is connected and integrated with a design proposal. If the proposed design does not answer the research problem after testing, design science researchers return to the suggestion step to investigate the existing requirements. The artifact is an output of the development phase, which constructs a new product, and is evaluated against the research criteria. In this study, the researchers develop a list of specifications as output, namely, artifact, which incorporates refugees' needs and daily living in terms of safety, climate conditions, stability, and social issues. The evaluation stage in other research models might recommend further research depending on the result, whereas the evaluation phase in design science presents further information and data of the artifact by experts that allow another round of the suggestion phase to formulate a new design proposal (Johannession and Perjons, 2012). In this study, designers and architects are involved to produce prototypes of shelters based on the application of a given specification list. The conclusion phase is the final stage of the research cycle, in which the output is the result that might, however, still deviate from artifact satisfaction. As shown in Fig. 1, Gregor and Hevner (2013) explained how an arrow exists between the conclusion and knowledge in the design science model, which is essential in testing the contribution of knowledge to the outcome of the research and makes itself a novel contribution to the body of knowledge.

IS involves two types of discipline, namely, behavioral science and design science (Hevner and Chatterjee, 2010). Natural and social science paradigms stand on problem orientation (Wieringa and Director, 2013) and define the problem that guides the hypothesis, data collection, and data analysis and then proves or disproves the hypothesis. Scientific methods are different from design science methods in which many empirical research methods describe, explain, justify, and predict the world, as shown in Fig. 2. Typically, scientific methods adhere to the following steps: asking questions, reviewing literature, formulating a hypothesis, collecting data, analyzing, and discussing (Geerts, 2011).

The previous table shows a comparison between empirical methods and design science in terms of steps. Steps 3 and 6 of design science, namely, developing an object and communicating the object, respectively, do not exist in scientific methods. The aim of a project in design science is to address a practical problem using an artifact, and the project may develop a new artifact from scratch or refine an existing one. Design science includes the cycle of assessing a practical problem, outlining the requirements, creating an object, and demonstrating and evaluating the object. Thus, creating a new artifact is required to finalize the activities of design science and achieve a knowledge base.

In short, the design cycle of design science is beneficial to the fields of theory and practice rather than in other research processes. The iteration process during the first four phases of design science provides opportunity for researchers to revisit and refine research results and address the explicated problem. As such, the design science rationale allows the recasting of the different stages of architectural design creation as evaluation iterative phases (Fig. 3). This study focuses on creating a list of specifications for the design of a refugee shelter, but the case study is aimed at method testing. Hence, results are a general solution to a general problem rather than a case-study-specific one, as in the aim of the design study methodology.

2.2. How to apply design science to solve design challenges: the research methodology

Design science focuses on real problems and offers a practical understanding of the gaps between the theoretical academic research discipline and the practical field. Purao (2002) argued that natural science research stands on existing and emerging phenomena without affecting the phenomena, and this condition creates barriers to delivering an original solution.

This study is the first attempt to follow the design science approach to deliver a full architectural design process, which is evidence-based, is user-centered, and responds to traditional "scientific" questions. To achieve this aim, this study tackles the design issue of reformulating

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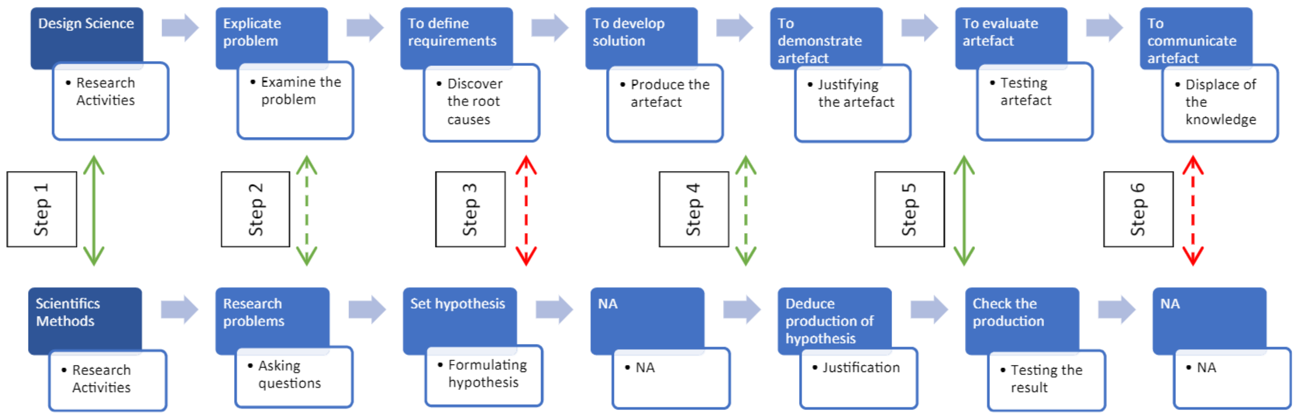

Fig. 2 Design science vs. scientific methods (authors' elaboration).

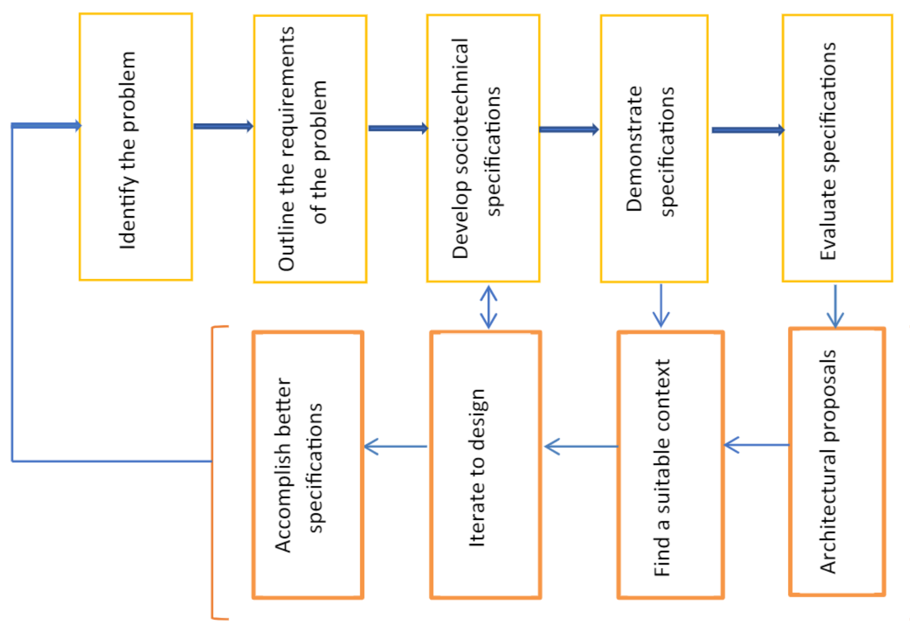

Fig. 3 Architectural proposals are evaluation phases in design science (authors' elaboration).

the design of refugee shelters. This design problem is selected because the current design of refugee shelters lacks a full understanding of the complexity of users' needs. Hence, the design science method is utilized to propose a new solution (artifact) that is suitable for application to refugee shelters in hot—dry climates. The artifact in this study is the list of specifications. The design science method is selected for the following reasons:

➢ Most academic research on refugees currently points to a limited understanding of the refugees' situation with unclear evidence presented in the literature. The use of design science as a method to innovate a proposed solution leads to the understanding of the challenges faced in refugee accommodation in camps. Ashmore et al. (2003) mentioned that scholarship on the required standards for a shelter is limited. The publications of UNHCR, Medecins sans Frontieres, Sphere, and the Shelter Project include guidelines and standards that provide alternative emergency shelters.

➢ Unlike behavioral science research, design science is solution oriented. The result comes from a scientific understanding of the theory and practical problems in the relevant field. Thus, the solution can be used by professionals to formulate a design that addresses problems by involving people in the process, which is driven through an iterative design cycle of data collection and analysis (Wieringa and Director, 2013).

➢ Many research strategies have been conducted to achieve the research aims, objectives, and results, although similarities exist between design science and other strategies, including case study and action research strategies. However, a difference appears in terms of epistemological paradigms because interpretivist perspectives produce a hermeneutic cycle of design that focuses mainly on the interpretation of the researcher in certain points of the field (Bryman, 2012). Design science implements multiple paradigms and aims at the generalizability of an artifact, whereas case study and action research do not necessarily aim at this last goal.

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- Previous studies have suggested that shelters tend to implement design performance and disregard stakeholders' requirements. Turner (2011) discussed that developing an artifact (i.e., the list of specifications in this study) occurs throughout the design science method, thereby providing connections among many factors in one process. This case applies to the current research in which different stakeholders are part of problem definition and solution, and some acts as users in different perspectives; thus, the final solution is a comprehensive way to combine all those factors in one single process. The design science method provides a foundation to conduct a process that supports the original solution by linking literature and survey analysis.

This study adopts the five phases of design science, which are required to achieve the outcomes of the research. Each activity is completed before the commencement of the next. Various techniques for data collection and analysis and strategies, such as survey, case study, direct observation, document studies, interviews, and questionnaires, as tools for data collection data are adopted, as shown in Fig. 4.

The following subsections discuss the individual activities undertaken within the design science framework.

3. Problem explication

Johannesson and Perjons (2012) argued that explicating the problem leads to an understanding of the practical problem and motivates the roots of the problem. The problem for the current research is the absence of adequate shelters to provide a response to refugees' needs.

The factors that contribute to the problem are used to develop an innovative solution. Specifications are formulated against certain criteria based on refugees' needs. The lack of integration among the manufactured design of shelters, their environmental aspects, and the cultural practices of refugees leads us to understand the roots of the problem, as shown in Fig. 5.

This phase is developed through a comprehensive literature review, which leads to a deep understanding of the problem and suggested solutions. Rocha (2011) stated that a literature review contributes to gaining a thorough understanding of a problem by formulating a theoretical background. Literature review has been complemented by fieldwork, which aims at investigating current and desire states to develop an *artifact*. Fieldwork includes informal interviews with the local government and unstructured interviews with refugees in the Al Za'atari Camp.

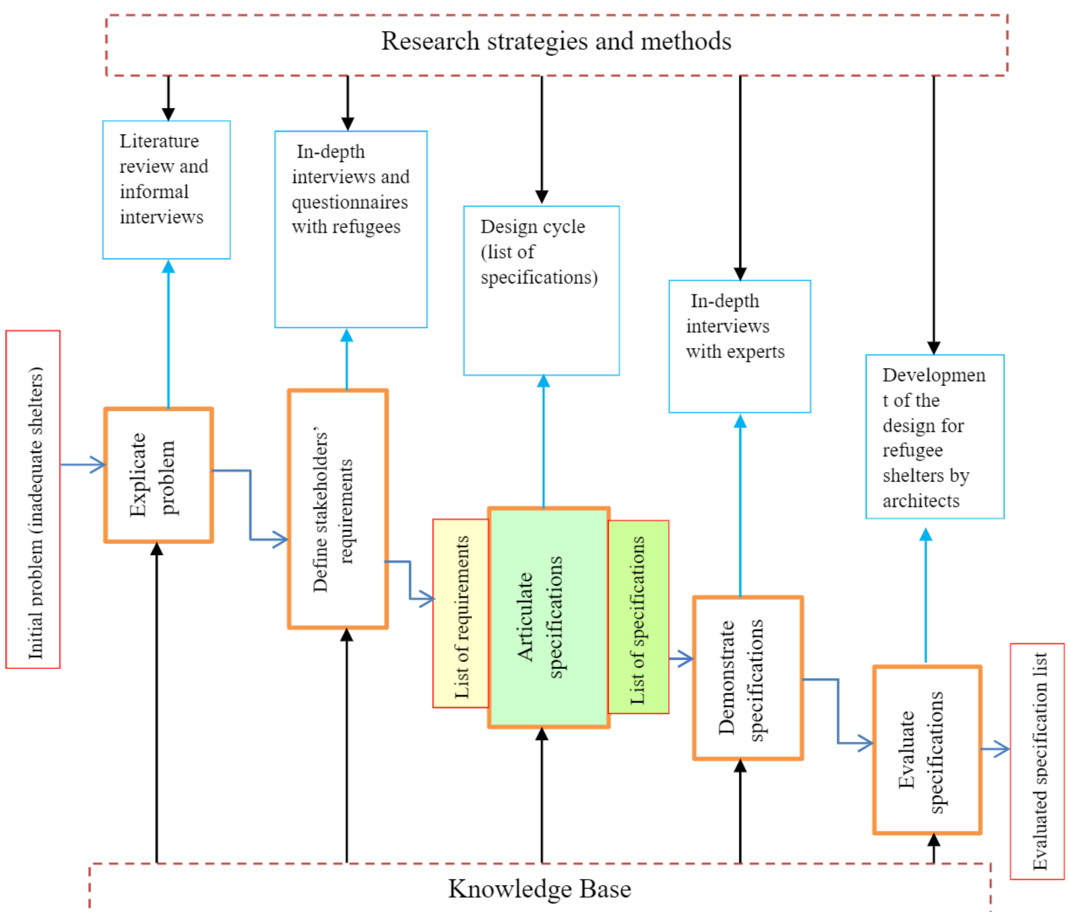

Fig. 4 Suggested use of research strategies in design science (Adapted by: Johannesson and Perjons, 2012, p. 44, p. 44).

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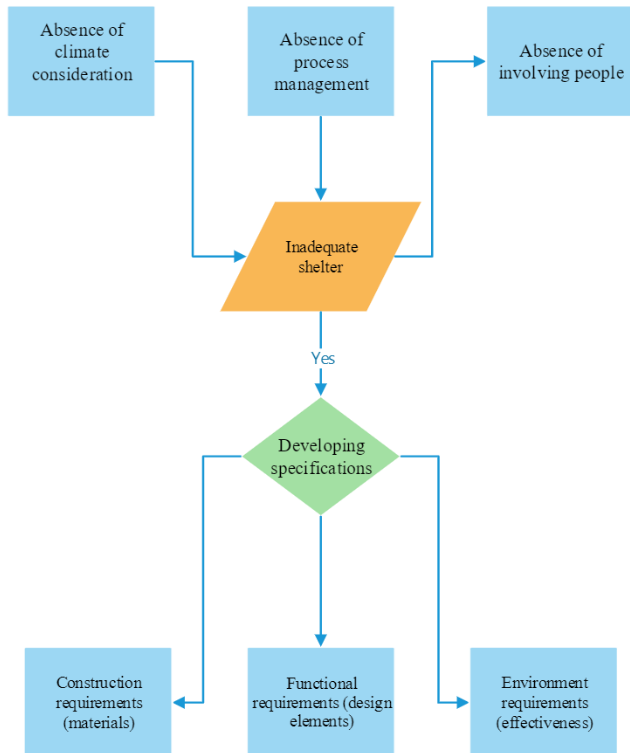

Fig. 5 Root causes of the study problem (authors' elaboration).

The literature review aims to achieve the following:

- distinguish how refugees are housed and what needs to be achieved;
- identify the theoretical aspects of the subject in relation to human needs and desires and place them by group of research criteria;
- cover the environmental and social contexts of the subject by identifying the existing problem in practice;
- discover the related variables of housing refugees and the environmental, social, and functional situations worldwide;
- identify methodological approaches and techniques to conduct the study.

This research focuses on the challenges faced to provide an appropriate shelter under limitations of funding, time management, and environmental circumstances in a hot—dry climate. Existing shelters are unsuitable for meeting the challenges of a hot—dry climate, and refugees face performance difficulties and social challenges in the shelters. These difficulties define the current state, whereas the desirable state is what refugees want by providing a shelter in combination with refugees' needs, other stakeholders' requirements, and environmental challenges.

Researchers, such as Johnson et al. (2006), Rawls and Turnquist (2012), Hadafi and Fallahi (2010), Ashmore et al. (2003), and Quarantelli (1995), have discussed the challenges in refugee settlements. They explained that these challenges include the need for rapid establishment, low cost per unit, and mindfulness to protect the environment. Many countries, including Turkey, Japan, Iran, and China, have experienced different disasters, such as earthquakes, tsunamis, and war-related displacement, and needed to provide numerous displaced people with adequate accommodation.

Refugees must be housed in emergency or transitional shelters or permanent shelters (Shelter Center, 2012). The difference in these shelters depends on the requirements in terms of time and cost. UNHCR would usually provide tents to secure and protect people in the first instance, although it can offer prefabricated shelters to meet complex or challenging living environments. However, regardless of whether the shelter is a tent or is made from prefabricated materials, other considerations are integrated into the design of the encampment. They include whether the structures are a canvass tent or prefabricated enclosure (Ashmore et al., 2003), are built from local materials, are built from manufactured materials, utilize local skills, or require the installation of developed technology from different countries.

Table 1 lists several existing shelter designs that are provided by different programs and organizations for refugees. These designs have been evaluated by the American Red Cross, the International Organization of Migration, the Oxfam Project, UNHCR, UNICEF, and the Norwegian Refugee Council (NRC). This work is derived from the Shelter Project (2009) with other international institutions and an institutional collaboration between UN-HABITAT and the International Federation of Red Cross in different regions facing disasters that make people move for safety, security, and stability reasons.

Each of these temporary housing solutions does not have clear methods that guide suppliers to offer shelters that would meet refugees' preferences. General criteria for ensuring shelter performance or shelter characteristics for refugees that consider many factors, such as climate difficulties and social challenges, are lacking. Most shelter construction is provided rapidly as an emergency response to a disaster, and no comprehensive methods that lead to the design and planning of shelters as defined by the users are available.

4. Establishment of research requirements

Determining the *artifact*; formulating, justifying, and explaining each requirement in terms of needs; and being realistic and original when clarifying the source of requirements, describing the literature, defining the involved stakeholders, and showing rigor in the study are necessary to define the requirements of the shelter.

The requirements clarify the context of research and support the originality of the *artifact*. Here, the research specifications are determined by the context and by stakeholders' interests and needs.

Defining the requirements includes identifying the characteristics of the problem, the suggested framework of previous studies in the same situations, technological opportunities, and stakeholders' needs. This research justifies how each requirement is essential based on interviews with stakeholders and secondary sources/literature. The

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Table 1 Cross analysis of chosen examples of shelters (authors' elaboration).

Region or Country/ Year/Organization	Shelter Construction	Implemented Method	Project Timeline
Afghanistan/Conflict/ Qala Camp/2009/ Pakistan-administered Kashmir	Tent, then transitional shelter	Material supporting implementation (Prefabricated structure)	4 months; three phases: tent provision, construction initiation, and construction completion
Gaza (Palestine)/ Conflict/2008/UN	House repair	Urban organization method	13 months; five phases: early recovery reconstruction plan, project implementation, assessment start, assessment process 1, and project completion
Georgia/Conflict/ 2009/NGO	House repair/Permanent/ Core housing	Design function implementation	7 months; five phases: draft of shelter strategy, registration community, policy change, construction initiation, and project completion
Rwanda/Conflict/ 2008/UN with local government	Permanent/Core housing	Material implementation	14 months; eight phases
Somalia/Conflict and drought/2009/ NGOs	Transitional shelter	Material implementation and urban upgrade	11 months; four phases: planning recruitment, procurement, construction completion, and project completion
Sri Lanka/Conflict/ 2007/NEO	Core shelter	Planning implementation	3 years; families' return, project start, core shelter completion, and completion of the rest of the core shelters
Bangladesh/2007/ Cyclone Sidr/ International organization	Core shelter and repairing	Repairing shelter implementation	22 months; six phases: assessment, test shelter, technical review, shelter construction, toolkit distribution, and project completion
India/Earthquake/ 2001/NGO with local organizations	Transitional shelter	Design implementation to reduce masonry falling	10 months; three phases
Italy Earthquake/2009	Shelter construction/ Permanent housing	Design implementation (modular housing unit)/long-life program	12 months
Peru/Earthquake followed by tsunami/2007/NGO	Self-built transitional shelter	Design implementation (using existing local structure and long-life material), demandable shelter	3 months; four phases: assessment, shelter prototype, funding, and project completion
Sri Lanka/2004/ Tsunami/National government	Construction transitional shelter to bridge the gap until reaching a permanent one	Design and construction implementation	9 months; three phases: prototype shelter, shelter materials, shelter completion
Uganda/Flood/2007/ International organization	Traditional round shelter	Design and local material implementation	The government started concrete block housing, which is expensive compared with traditional houses, with less attention to individual needs.
Bangladesh/Conflict/ 1975/CUNY Center	Shelter and camp planning	Material and planning implementation	4 years; six phases: displacement into camp, shelter design, field testing of prototype, consultation, construction period, and evaluation
India/Conflict/1971/ CUNY Center	Planning housing and material support	Planning organization method that meets basic needs, sustainable upgrading, and camp	9 months; three phases

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requirements are reconsidered to formulate a first draft of specification guide to establish refugee shelters in hot—dry climates that connect theoretical requirements and practices. The originality of specifications, stakeholders' interests, and ranking of their needs are considered sources for outlining the requirements. Variables, such as different shelter configurations, topographical and cultural variations, and microclimate differences, mean that one basic design may not suffice in all cases; this condition guides the designers to the direction of multiple solutions in terms of environmental alterations and social uniqueness.

The following field strategies are adopted to enable the creation of the outline *artifact*:

4.1. Interviews

This strategy is used to identify the requirements and needs of stakeholders (face-to-face interviews).

4.2. Observation

The researchers observe refugee camps situated in desert conditions. Jordan is an ideal location for this work, considering that it meets the climatic criteria and has a long history of accommodating refugees. The researchers determine how refugee agencies deal with accommodation issues raised by refugees in existing camps.

4.3. Analyzing

NVivo is used to analyze in-depth interviews and qualitative data. A preliminary outcome is a road map for explicating the problem, outlining the requirements, and defining the artifact. A further analysis by multicoding in NVivo allows for the development of the list of specifications.

Data sources include literature and observation, and data collection tools include in-depth interviews and questionnaires with refugees, who are asked to identify an extensive list of functional and social requirements. Experts from different organizations are also asked to explain the current accommodation strategy and the potential for improvements in the future.

5. Development of a list of specifications

The proposed *artifact*, i.e., the list of specifications, is developed under certain criteria. Johannession and Perjons (2012) mentioned that strategies and methods for developing specifications are less essential than other phases of design science; however, observations, interviews, and documented studies may be used to develop and design an innovative solution. The current research includes qualitative data in form of in-depth interviews with refugees, in addition to other observations and documents that support the formulation of a list of specifications.

Specifications describe the requirements of refugee shelters through design elements, urban organization, and social and cultural features. They reflect the understanding of what users need in terms of activities and living conditions.

Specifications also describe the requirements under each criterion, including safety and security, comfort, social context, modularity and flexibility, stability, demountability, durability, and independent constant energy. Each criterion is described by several specifications. For example, comfort is described by temperature, humidity, and sun radiation. Social context is described by space standards inside and outside the shelters.

6. Demonstration of specifications

A specification list is demonstrated by the researchers by validating feasibility in practice (Vaishnavi and William kuechler, 2007). This validation is achieved by meeting experts, researchers in the field, involved organizations, and any other institutions that influence decision makers. Data collection tools include in-depth face-to-face and virtual interviews, which are analyzed using NVivo. Various geographical locations are used to canvass opinions on the revisit to achieve a comprehensive list of specifications that consider all influencing factors. This step serves to validate the list or identify deficiencies leading to amendments and a further iteration of the process.

Specifications must be demonstrated in daily activities as contributing to real life and practices to determine if we can solve several of the problems (Järvinen, 2007). A camp in Jordan is the real-life case in this study to demonstrate the specifications. This camp is selected because the crisis in refugee immigration in this camp, aside from climatic conditions, is apparent. This condition makes it a suitable place to investigate the functional components of specifications.

7. Evaluation of the specification list

Evaluating an *artifact* is about testing how much it can solve an explicated problem in practice (Holmstrom et al., 2009). Any research strategy and method, such as a case study in which interviews and questionnaires are appropriate tools for data collection, can be used by researchers in the evaluation.

Two subactivities are performed to evaluate *artefact*s. The first one is choosing an evaluation strategy, which is performed in two stages, namely, "Ex ante and ex post evaluation. Ex ante evaluation means that the *artifact* is evaluated without being used, while ex post evaluation requires the *artifact* to be employed. An ex ante evaluation often makes use of interviews, where experts express their views on an *artifact*" (Johannession and Perjons, 2012, p. 90).

In this research, specifications are evaluated by testing how to solve the explicated problem. Architects and engineers are interviewed and asked to illustrate a proposed shelter on the basis of the list of specifications provided. This method of evaluation allows for any limitations in understanding of the specification and the efficiency of proposing shelter illustrations to confront refugees' needs.

Peffers et al. (2007) indicated that awareness of the problem that appears as a gap between the current state and the desirable state is vital when using design science. The current situation of refugees is described as

Table 2 Data collection categories.

Name
Framework of shelter specifications
1. Functionality—flexibility—shelter performance
2. Manufacture and materials—durability—design elements
1. Social and culture norms—adapting urban compatibility
Needs' solutions
1. Better shelter
2. Go back home
3. Normal daily life activities
4. Secure environment
Refugees' challenges
1. Climate impact
2. Comfortable shelter
3. Overcrowded sector and services
4. Safety and security
5. Sense of the place
6. Service control—electricity and water
7. Stability
Specifications' benefits
1. Climate control
2. Environment respect—insects and rodents
3. Health control
4. Adding new elements—modularity
5. Sanitation and hygiene

inappropriate with a lack of suitable shelters. Their desire is to establish a new state by obtaining an appropriate shelter to protect them from external factors, such as climate challenges, diseases, and poor sanitation and services. The specifications present the proposed innovation of the study to resolve the practical problem of providing refugees with a suitable shelter in a hot—dry climate. However, the evaluation phase of the solution is crucial in establishing why and how such a solution can address the problems faced by refugees in hot—dry climate camps and justifying the theoretical agreement in conducting scientific methods (March and Smith, 1995). The demonstration phase rests on the opinions of professionals and experts in housing refugees in hot—dry climates.

Specifications must be demonstrated in daily activities as contributing to real life and practices to determine if several of the problems can be solved (Järvinen, 2007). The performance-based and performance-driven rationale (Shi, 2010) links the concept of specifications and the performance required by the shelters' users. The evaluation phase occurs by involving architects in the illustration of proposed shelters depending on the list of specifications to investigate the ability of the list and determine if the list is adequate to address the practical problem in which researchers are not involved in the production of conceptual illustrations.

In the first stage of refugee interviews, this research analyzes empirical data by using NVivo software and coding the research questions into four groups, i.e., framework of shelter specifications, needs' solutions, refugees' challenges, and specifications' benefits.

As shown in Table 2, the research target focuses on four categories; each of them is detailed through the literature and previous practices in refugee shelters. Following this stage, the researchers target refugees and interview them by asking questions, as presented in Table 3.

Table 3 shows 23 questions, which are distributed with groups and related to certain requirements of refugees' needs and settlement challenges, such as climate difficulties, manufacturing design elements and materials of the shelter, discontinuous electricity and water, instability, and social and cultural differences, including settlement challenges, security, and protection of refugees. After interviewing the refugees, the researchers analyze their responses by coding. Verification is completed by asking design experts to use the list of specifications and discussing the outcomes from this test.

8. Testing design science in developing architectural solutions: insights from the case study

8.1. Presentation of the case study

The Al Za'atari Camp in Jordan, which is the second largest camp in the world as reported by the United Nations High Commissioner For Refugees (2013b), is located 10 km east of Mafreq and was opened in early 2012 Fig. 6.

The Al Za'atari Camp grew out of a desert area and is the second largest camp in the world after the Dadaab Camp in Kenya, which houses 329,811 refugees; it has grown to become the fourth largest city in Jordan (Ledwith, 2014).

The camp initially had a planned capacity of 20,000 refugees but reached 45,000 by the end of 2012. The figure was 65,000 in early 2013 and continued to rise to 76,000 refugees in February 2013. Later in 2013, numerous Syrian refugees crossed the Jordanian border because of instability in southern Syria. The number of Syrian refugees peaked at 156,000, with 3000 to 4000 refugees arriving each night. The Al Za'atari Camp, therefore, had been in high demand to provide protection and services for unexpected numbers of refugees (United Nations High Commissioner For Refugees, 2013a). Most refugees had settled in Al Za'atari from Dara and worked in agriculture, although several were skilled workers, such as builders and carpenters. By 2015, the estimated number of refugees was 83,000, which was distributed among 13 sectors. Each sector contained blocks, communities, and shelters, as shown in Fig. 7. A report by the UNHCR in April 2016 stated that Al Za'atari was housing 79,551 Syrian refugees.

Al Za'atari has a high poverty rate, with two-thirds of the refugees categorized below the national poverty line, as determined by the United Nations High Commissioner For Refugees (2016).

Refugees initially settled in tents, after which they were arranged in new caravans in the same informal layout and organized in U shapes to be close to relatives and friends in courtyards and gathering spaces.

The United Nations High Commissioner For Refugees 2012 report specified white canvas tents with blue UNHCR stamps with the following dimensions: 660 cm × 400 cm; the maximum height is approximately 140—220 cm. One space is provided for four to six people, and refugees are

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Table 3 Interview questions (authors' elaboration).

	Questions	Options	Responses
Manufacturing design elements and materials of shelters	1. What are the initial modifications that you applied to your shelter?	a. Adding a private shower	
		b. Adding a private bathroom	
		c. Adding a washing area	
		d. Adding a private kitchen	
		e. Water tank	
		f. Extending by adding a tent	
		g. Supporting insulation	
		h. Supporting electricity services	
		i. Supporting security services	
		l. No modification	
		m. No answer	
		Total	
	2. What are the problems that need to be maintained permanently in your shelter?	Rain water leak from any part of the shelter	
		Dismantled parts of the shelter	
		Rotting in parts of the shelter	
		Window and door damages	
		Others (please specify)	
		Sanitation problems	
		Rodent problems	
		No problem	
		Electricity problems	
		No answer	
		Total	
	3. What maintenance problems have you faced in your shelter?	Window and door manufacturing problems	
		Floor manufacturing problems	
		Roof manufacturing problems	
		Climatic manufacturing problems	
		Manufacturing material problems	
		Nothing	
		Everything	
		No answer	
		Total	
	4. Which of the following factors influence your satisfaction of the shelter?	Location of shelter to nearest services	
		Location to the nearest relatives or friends	
		Outside the related area	
		Location of shelter area compared with other dwelling areas	
		Shelter atmosphere	
		Provision of services (sanitation, insulation) inside the shelter	
		No answer	
		Total	
	5. What is the reason for extending your stay in the shelter?	Shortage of spaces provided	
		Shortage of internal existing services	
		Increase in the number of family members	
		Social and cultural aspects	
		Unclear reason	
		No answer	
		Total	
Discontinuous electricity and water	6. What is the water source for daily household use?	Supply system (network infrastructure)	

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Table 3 (*continued*)

	Questions	Options	Responses
		Water is being bought on our expense	
		No stable water source	
		We do not get water	
		No answer	
		Total	
	7. Is electricity provided to your shelter?	Yes	
		No	
		Total	
Instability	8. What was your occupation back in your home?	Farmer	
		Professional occupations	
		Office occupations	
		No job	
		Housewife	
		Student	
		No answer	
		Total	
	9. Are you working now?	Yes	
		No	
		No answer	
		Total	
	10. Do you see yourself living in the same shelter after five years?	Yes	
		No	
		Total	
Social and culture differences	11. What kinds of problems happen in the camp?	Financial problems	
		Family problems	
		Governmental problems	
		Neighborhood problems	
		Service problems	
		Psychological problems	
		No problem	
		No answer	
		Total	
	12. Do you share the outside area of the shelter with the neighbors?	Yes	
		No	
		Total	
	13. Where do you live in the camp?	Near friends and relatives	
		Near public services	
		Near the camp center (shopping area)	
		Far from the center	
		Near specific services (water/electricity)	
		Total	
Security and protection	14. Which of the following do you consider your most important need?	Security and safety	
		Food and nonfood item	
		Comfortable shelter	
		Social ponding	
		Job	
		Educational quality	
		No answer	
		Total	
	15. Have your sense of safety in your shelter changed by time?	Feeling safer	
		Feeling the same	
		Feeling less safe (explain)	
		No answer	
		Total	
	16. Have you heard about fires that resulted from	Always	

(*continued on next page*)

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Table 3 (*continued*)

	Questions	Options	Responses
	cooking inside the shelters?	Sometimes	
		Rarely	
		never	
		Total	
	17. Have you suffered from new diseases after moving to the camp?	Yes	
		No	
		No answer	
		Total	
	18. What are the four most important services you need to improve your quality of life?	Food	
		Water and sanitation	
		Type of shelter	
		Medical services	
		Special medical services	
		Education services	
		Security/safety	
		Livelihood and employment	
		Legal rights and advice	
		Back to my home	
		Electricity services	
		Everything	
		No answer	
		Total	
Climate difficulties	19. What are the weather conditions that affect the shelter?	High temperature	
		Low temperature	
		Rain	
		Snow	
		Dust	
		Wind	
		Humidity	
		No answer	
		Total	
	20. What do you use/do to protect yourself from high temperature inside your shelter in the summer?	Electric ventilators	
		Going out of the shelter	
		Opening windows and doors	
		Nothing	
		Staying at the shelter	
		Protection using water	
		No answer	
		Total	
	21. What do you use/do to protect yourself from low temperature inside your shelter in the winter?	Electric heaters	
		Gasoline heaters	
		Making fire	
		Using blankets	
		Wearing extra clothes	
		No answer	
		Total	
	22. What problems do you face any problems concerning rain water?	Water entering from the doors and windows of the shelter	
		Water pooling around the shelter	
		Humidity inside the shelter	
		Leakage from the ceiling	
		No problems	
		No answer	
		Total	
	23. To what extent does strong wind affect the shelter?	Strong effect	
		Average effect	
		Weak effect	
		None	
		No answer	
		Total	

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responsible for assembling their tents. The tent's lifespan depends on its use, climate conditions, and how it has been stored. Usually, they do not last more than 12—18 months, although several Syrian refugees stayed in such tents for more than 24 months with an inappropriate quality of life. Cramped living space affected intimacy in the family, especially partners and children without access to private kitchens and toilets. Eight percent of refugees installed their private toilets and kitchens with their own money due to difficulties in using public services.

Shelter performance, service provision, and the difficult economic situation affecting the livelihood of refugees are the main inconveniences that refugees suffer from during their daily activities. The shortage of adequate shelters forced the majority of Syrian refugees to live in unsatisfactory conditions. Such conditions included poor ventilation, condensing mold, and extremely high or low temperatures in bathrooms and kitchens. United Nations

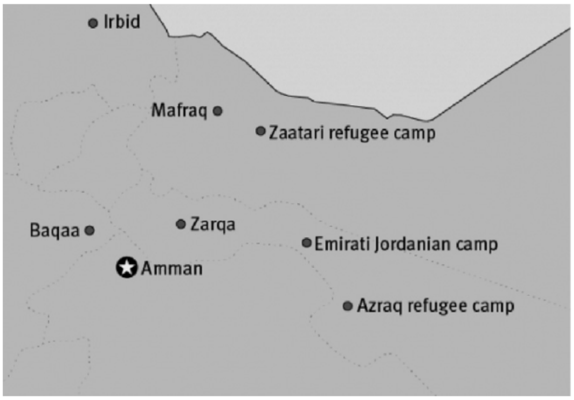

Fig. 6 Location of the Al Za'atari camp (Source:www.google.jo).

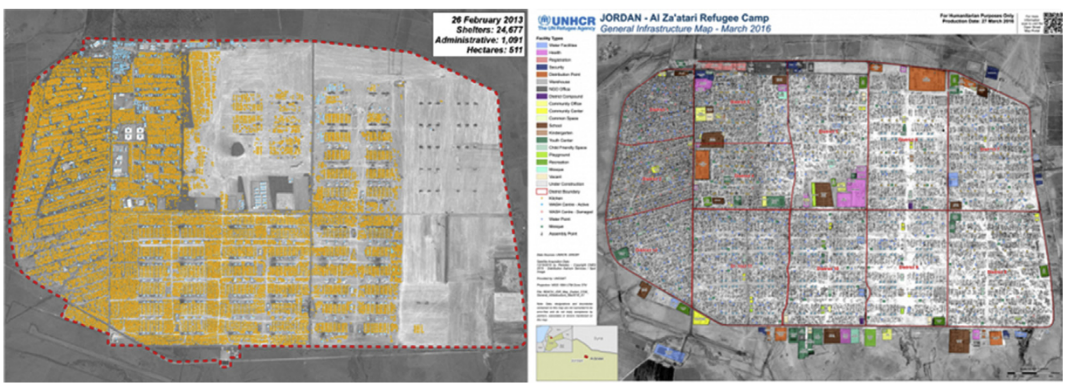

Fig. 7 Al Za'atari camp between 2012 and 2016 (Source: www.google.jo).

Table 4 Research activities relating to design science phases (authors' elaboration).

Phases	Fieldwork/Direct Study Stages	Stakeholders	Data Collection Tools
Phase one: Explicate the research problem	Reviewing and investigating the literature		
Phase two: Outline requirements	First stage (four visits to the Al-Za'atari Camp)	• Refugees • Local government	Unstructured interviews
	Second stage (15 visits to the Al-Za'atari Camp)	• Refugees	≫ 24 in-depth interviews ≫ 146 completed questionnaires with refugees
	Third stage (10 visits to the Al-Za'atari Camp) Manufacturing local companies	• International organizations • Local manufacturing experts	≫ seven in-depth interviews with selected staff ≫ three in-depth interviews with selected manufacturing specialists
Phase three: Develop a specification list	Generating specifications using the result of the literature review and the findings of the field study		
Phase four: Demonstrate specifications	Fourth stage—online survey with experts	• Practitioners • Academics • Researchers • Planners	≫ 30 in-depth interviews
Phase five: Evaluate specifications	Illustrating shelter design proposals by local architects		

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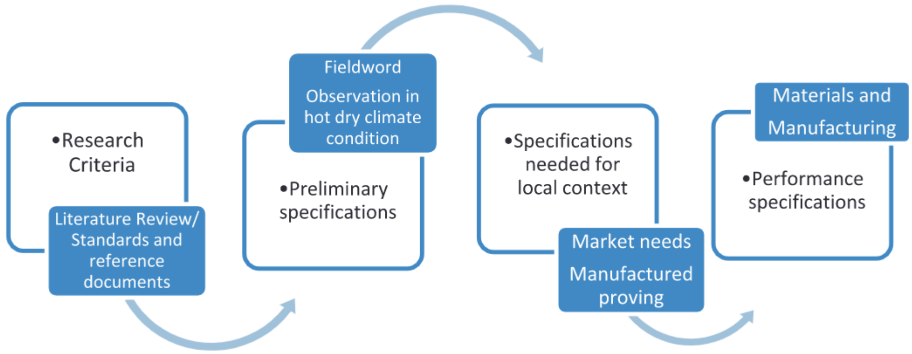

Fig. 8 Criteria and specification stages (authors' elaboration).

High Commissioner For Refugees (2014) recorded that 8% of refugees who decided to live outside the camp have a secure and safe shelter. Humanitarian organizations and local governments concealed the temporary situation without involving survivors in this idea. Their concentration on maximum speed and low costs appears to be a problematic situation when permanent measures are the only solution for refugees after two years of residency inside the camp (Hadafi and Fallahi, 2010).

United Nations High Commissioner For Refugees (2014) discussed various challenges to connect unit performance and design requirements, and a 2014 report by Jordan's

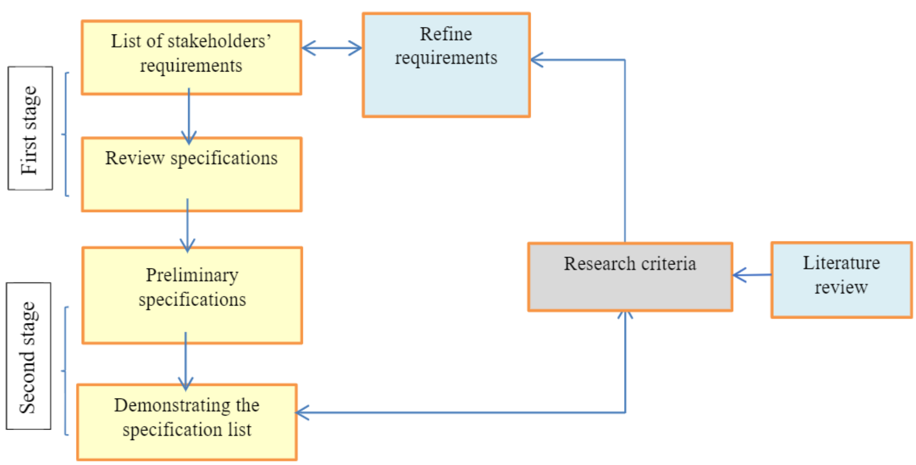

Fig. 9 Cycle of establishing specifications (authors' elaboration).

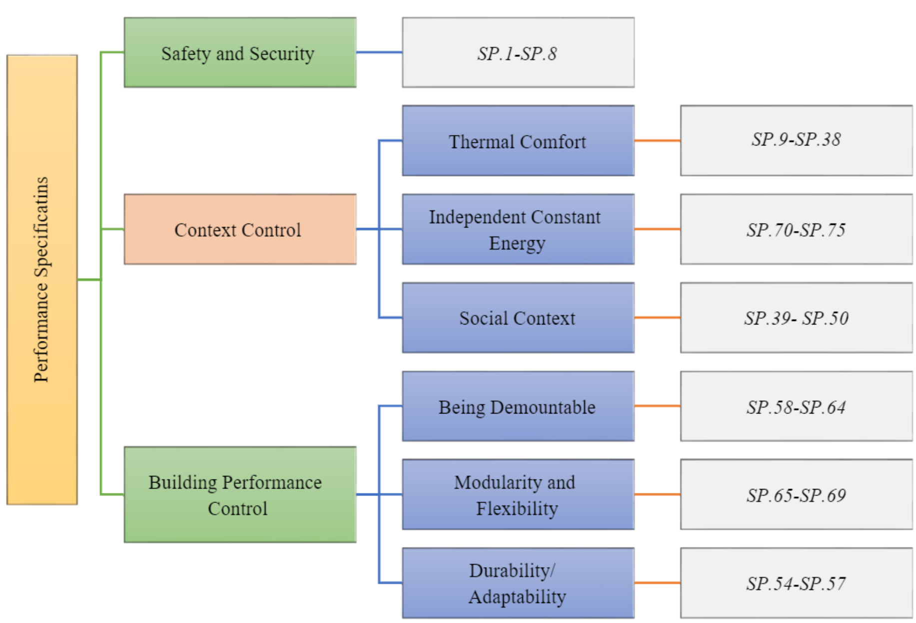

Fig. 10 Specification tree (authors' elaboration).

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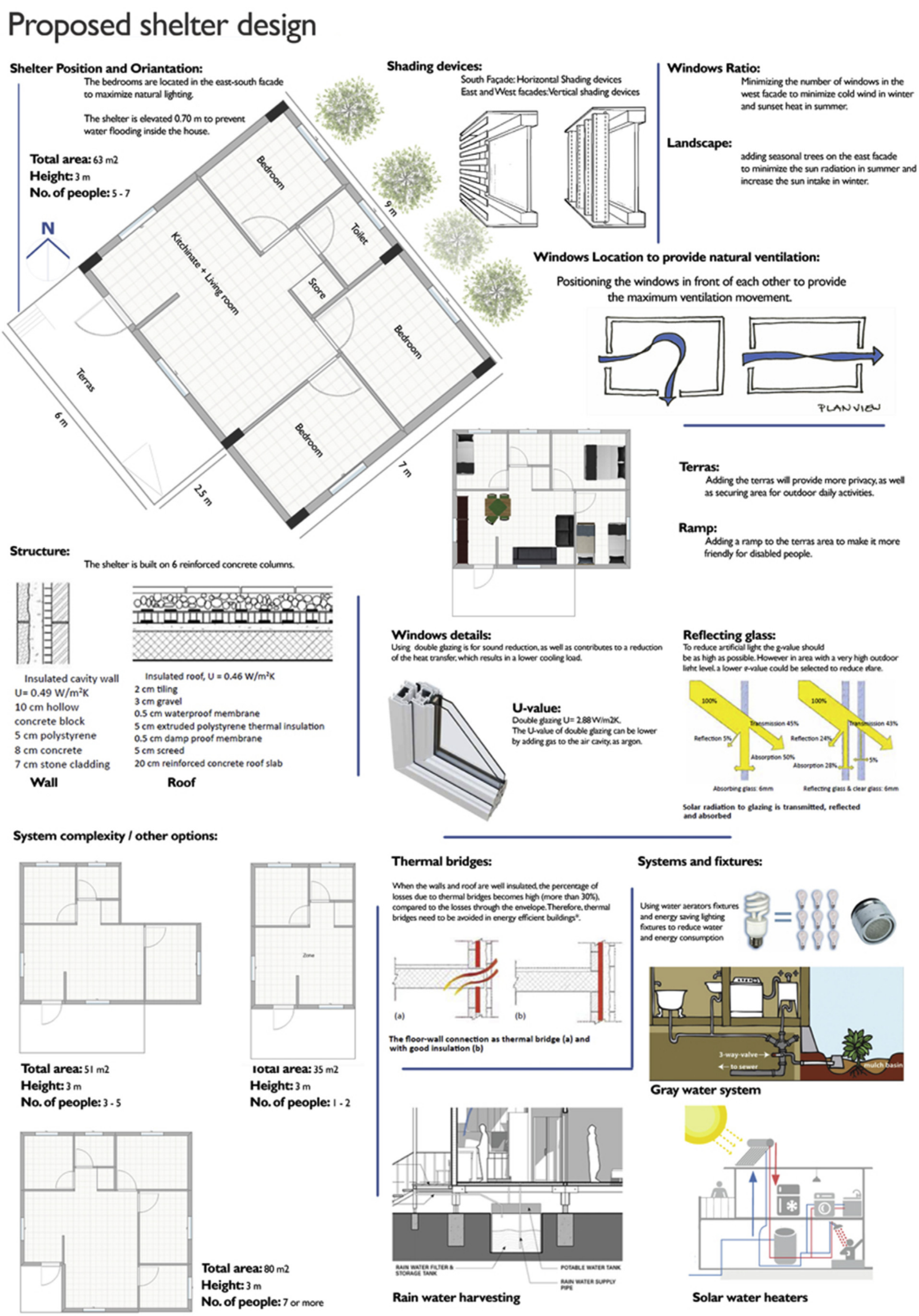

Fig. 11 Proposal No. 1 (Source: Architect No. 1).

Fig. 12 Proposal No. 2 (Source: Architect No. 2).

water ministry identified the challenges presented by pollution due to the absence of sewage system planning (Norwegian Refugee Council, 2014).

8.2. Data presentation

Research techniques include interviews and questionnaires regarding the following design science phases, as shown in Table 4:

- Phase one aims to explicate the problem by conducting a literature review of previous studies to define and clarify the problem.
- Phase two is divided into two stages. The first stage aims to define the requirements of the problem. Informal interviews with local government officials in the Al Za'atari Camp explain the context of refugees and formulate and design questions for the next step in phase two. The second stage includes in-depth and structured interviews in which the former comprises 29 refugees to focus on their needs. The results of the interviews confirm the initial findings, with 147 refugees explaining the connection between refugees' needs and settlement challenge variables. In the same phase, the researchers conduct in-depth interviews with local humanitarian organizations in the Al Za'atari Camp and with local prefabricated manufacturing companies. As a result of the two stages, a list of requirements from the stakeholders is provided, thus enabling the creation of the list of specifications.
- Phase three is about developing the list of specifications for refugee requirements based on the literature review and stakeholders (which are the local government, local prefabricated manufacturing companies, and NGOs in Jordan, mainly the UNHCR).
- Phase four aims to demonstrate the requirements; in-depth interviews are conducted with experts, professionals, architects, engineers, and researchers in

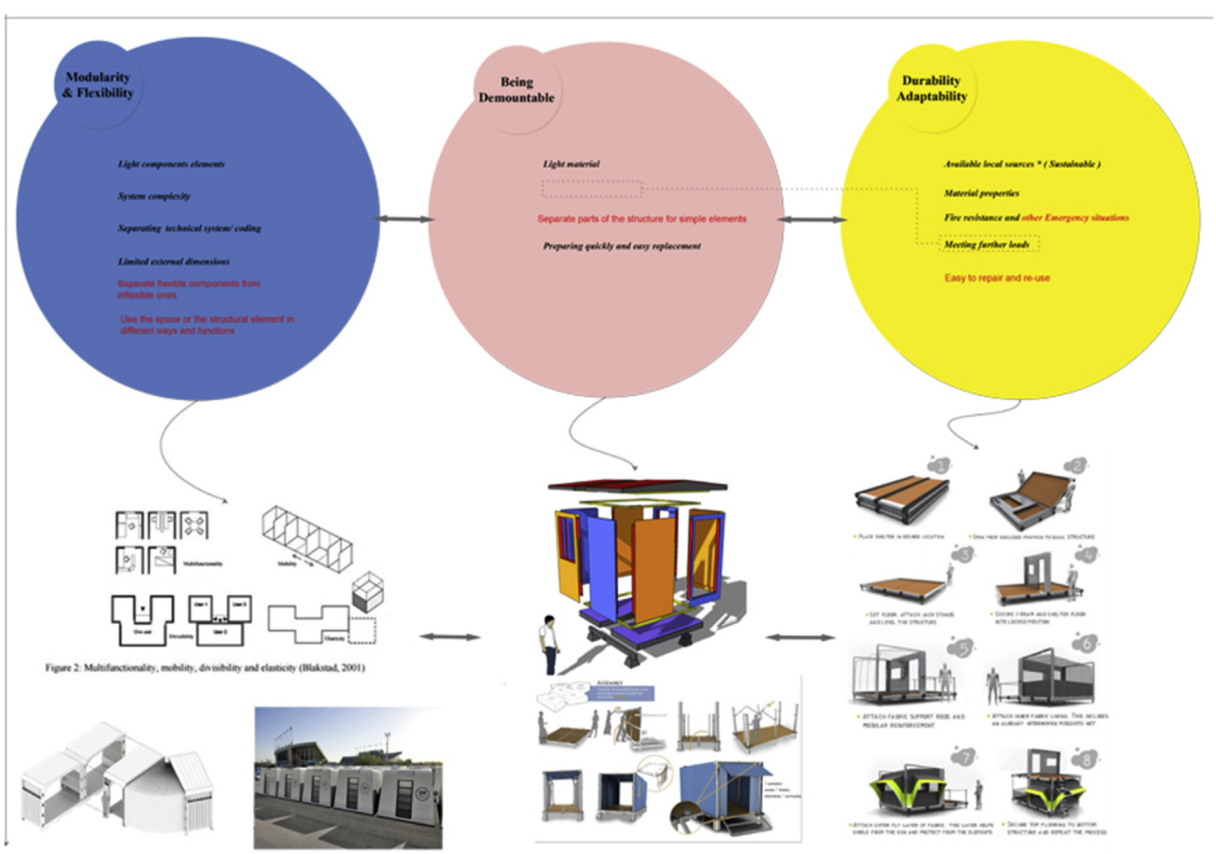

Fig. 13 Proposal No. 3 (Source: Architect No. 3).

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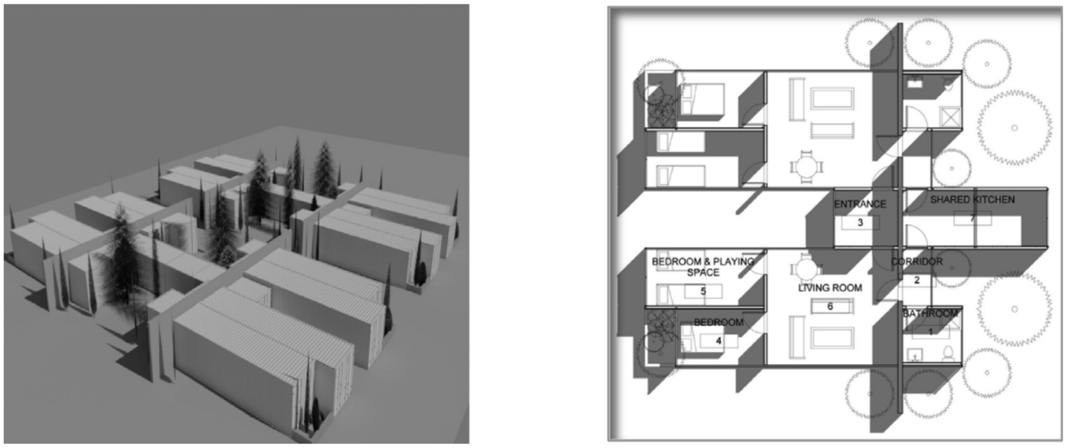

Fig. 14 Proposal No. 4 (Source: Architect No. 4).

housing refugees. This phase provides the benefit of using the design science method to reformulate the specification list according to the design cycle and iteration of the method.

- Phase five is the evaluation phase in which the researchers present the specification list to architects for the illustration of design proposals for refugee shelters.

The contributors are selected on the basis of given criteria. One is that they have to possess a wide knowledge of refugees' situations concerning their needs and challenges regarding the environmental impact (in a hot—dry climate), social need, and shelter implementation. All participants are also involved at different levels in accommodating refugees in camps, whether they are the main stakeholders, such as refugees, or experienced people in this field, such as researchers, architects, and NGOs.

8.3. Artifact: a list of specifications for designing shelters in hot—dry climates

This research develops a list of specifications of a refugee shelter that reflects the needs of users in hot—dry climates. Specifications are guidance and instructions, which are routinely used throughout the manufacturing phase to enable the implementation of products or processes that meet the needs and specifications supported by designers and engineers and to frame design problems and reach design objectives (British Standard Institution, 2001). Specifications guide the required function, structure, and desired behavior; accordingly, the structure embodies a multifaceted architecture, and behavior appears when specifications are implemented. Specifications as processes refer to the design process inside the construction of the project being managed (National Building Specification, 2008), whereas specifications as products are a description of the product quality. In this research, specifications establish the guidance to achieve a shelter for refugees in hot—dry conditions.

Thomas (2004, indicated in the National Building Specification, 2008) argued that specifications have various types, such as standard descriptions and performance. Performance specifications describe how the result is achieved without giving detailed technical description, whereas description specifications require these technical details (British Standards Institution, 2001). The current study follows performance specifications that lead to effective refugee shelters in hot—dry climate conditions, as shown in Fig. 8.

This study establishes specifications by producing outline performances of main specifications in the first stage and then refining specifications in the second stage, as shown in Fig. 9.

Specifications are provided in two stages. In the first stage, the outline specifications are offered by criteria based on literature review and the results of interviews. Criteria are first formulated from the literature based on theories of human needs, refugee studies, and involved organization reports. Specifications are then related to the following criteria: safety and security, social context, comfort, stability, flexibility and modularity, demountability, durability, and having constant energy. The specification tree shown in Fig. 10 offers a simplified view of the articulated list of 75 specifications, which is developed while moving forward from the initial list derived from the literature and then checked through the iterative verification process. The complete list is presented in Appendix 1.

Once the list of specifications (the *artifact*) is created, the evaluation phase is conducted by asking local architects to produce design proposals of shelters in a hot—dry climate based on the specification list. The proposed designs contain different illustrations of refugee shelters. The architects' proposals offer descriptive information on the design elements in the form of plans, elevations, sections, three-dimensional views, materials, structural and constructional solutions, and required services to answer the question of how well the specification list solves the refugees' problem. The researchers consider providing the specification list without any guidance, comments, and suggestions or influencing the direction of the proposals in any way.

The result of the evaluation phase gathers various alternative proposals, which demonstrate the applicability of the specifications to produce different shelters'

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prototypes consistent with the given criteria. The following figures show the result of the evaluation phase. Proposal number one (Fig. 11) prioritizes safety and security and applies them through structural elements, which make the unit suitable for people. The design considers thermal comfort and natural ventilation.

Proposal number two (Fig. 12) takes the shape of an onion dome, and each dome comprises eight segments that can easily be dismantled by sliding through channels on both sides of each segment. The designer considers thermal comfort through a raised cylinder to allow hot air to escape through a hat-like top, which contains several blades and rotates along a circular base by the force of the external wind current. The designer arranges a connector unit between two units that contains a bathroom and a small storage area on one side and a passageway on the other. Colored patterns can be fixed to the external skin to make a colorful dome.

Proposal number three (Fig. 13) depends on an infographic diagram to demonstrate the proposed solution, dividing the criteria into four main factors, namely, materials, climate condition, structural elements, and site/urban planning. All of these factors are related to design performance. The designer also addresses safety by illustrating the provision of a secure environment in two ways, namely, emotional and physical safety.

In proposal number four (Fig. 14), the designer creates a solution by using a shipping container as one of the main constituents of the housing module that can be repeated with some variations and iterations to make it more case specific. Regarding structural stability, a shelter is fixed by a layer of concrete footings as a base. The heart of every house is the kitchen, which is to be shared, possibly by at least two families. For flexibility and modularity, the layout is created in accordance with families of an average of four to five people.

In short, the various solutions offered by different designers prove the flexibility of the specification-based approach. The rigorous methodology applied to create the list of specifications in relation to the main criteria asserts that the proposed solutions are user centered.

9. Conclusions

The main aim of this study is to demonstrate the suitability of the design science approach to articulate the creative design process through a structured set of iterative steps. After a gap is determined in the published research on the link between shelter performance and refugee needs (explicate the problem, stage one of the design science method), the process achieves the provision of specifications in terms of the shelter itself. This provision is achieved by creating a new *artifact*, which takes the form of a list of specifications developed under research criteria in this study. This list will be followed when designing a shelter proposal in hot–dry climates for refugees. This outcome is evaluated by manufacturing experts and architects.

The production of a prototype clearly demonstrates that the objective is achieved. Producing any prototype means understanding and grasping the list of specifications in terms of the language explanations, technical requirements, and methodological approach of the list. The objective is achieved not because of what the prototype looks like or which materials are used but because it proves that a suitable process occurs in understanding the users' needs and considering the diversity of needs according to the context conditions.

The adoption of the design science method allows the fieldwork to uncover unique insights into connecting the theoretical and practical aspects. The connection among the phases of design science is the key issue of practical contribution in terms of iteration flexibility, that is, going back and forth among phases based on the situation. Such iteration is a unique strategy of methodological stance compared with other traditional methods.

The original contribution of this study is the demonstration that the design science method can be a suitable framework in the architectural design field.

Finally, this study contains a general approach useable by humanitarian organizations while designing shelters, thus bridging the gap between previous practices of individuals and combining stakeholders' needs and social and cultural aspects.

Appendix. List of specifications

A.1. Criteria one: Safety and Security

Specification one: Fear protection
Specification two: Fire safety
Specification three: Structure protection
Specification four: Hygiene of shelter spaces
Specification five: On-site sewage system
Specification six: Size of camp's block
Specification seven: Close distance between shelters and travelling time
Specification eight: Maintain shelter

A.2. Criteria two: Comfort

A.2.1. Thermal Comfort

Specification nine: Air temperature
Specification ten: Humidity in interior air
Specification eleven: Wind direction
Specification twelve: Air speed
Specification thirteen: Sun radiation
Specification fourteen: Precipitation
Specification fifteen: Planning of suitable plot
Specification sixteen: Determination

A.2.2. Acoustic comfort

Specification seventeen: Wind sound
Specification eighteen: Sound permeability
Specification nineteen: Acoustic insulation

A.2.3. Olfactory comfort

Specification twenty: Air quality

A.2.4. Visual comfort

Specification twenty one: Glare, Illumination and color

A.2.5. Shelter comfort

Specification twenty two: Settlement
Specification twenty three: Land characteristics
Specification twenty four: Shelter elements weight
Specification twenty five: Shelter height
Specification twenty six: Shelter lifting
Specification twenty seven: Considering disabled users

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Specification twenty eight: Shelter wall
Specification twenty nine: Shelter floor
Specification thirty: Foundation appropriate
Specification thirty one: Window size
Specification thirty two: Glazing
Specification thirty three: Cross ventilation
Specification thirty four: Roof characteristics
Specification thirty five: Shelter's water drainage channel
Specification thirty six: Preventing dust
Specification thirty seven: Providing shaded areas
Specification thirty eight: Insect screen

A.3. Criteria three: Social context

Specification thirty nine: Accessibility and integration
Specification forty: Adding portable elements
Specification forty one: Involving refugees in the construction of shelters
Specification forty two: Ability to repair
Specification forty three: Productivity-small scale commercial activities
Specification forty four: Intimacy between people
Specification forty five: Oriented shelters and streets in the same community
Specification forty six: Community road organization
Specification forty seven: Access to shelter
Specification forty eight: Visual boundaries
Specification forty nine: Protection
Specification fifty: Participation

A.4. Criteria four: Stability

Specification fifty one: A pattern of independent existence/stability
Specification fifty two: Structure stability
Specification fifty three: Dignity- with new community connectivity

A.5. Criteria five: Durability/Adaptability

Specification fifty four: Available local sources
Specification fifty five: Robust strong material
Specification fifty six: Shelter skin
Specification fifty seven: Mechanical ventilation system

A.6. Criteria six: Being Demountable

Specification fifty eight: Light material
Specification fifty nine: Build efficiently to minimize temperature variation
Specification sixty: Structure elements
Specification sixty one: Joint connection-details
Specification sixty two: Considering fixed base of shelter
Specification sixty three: Considering time of erecting shelter
Specification seventy four: Ability to repair-usability

A.7. Criteria seven: Flexibility and Modularity

Specification sixty five: Separate technical system / Coding
Specification sixty six: Enabling mechanical system
Specification sixty seven: System complexity
Specification sixty eight: Ability to extend
Specification sixty nine: Less cutting- consider the frequency of replacing and building shelters (affordability)

A.8. Criteria Eight: Independent constant energy

Specification seventy: Addressing shelter
Specification seventy one: Energy produced for local grid
Specification seventy two: Collecting solar radiation/ adding elements
Specification seventy three: Material storage / Cooling and Heating capacity
Specification seventy four: Rain harvest
Specification seventy five: Grey water system

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