From Shelter to Home: Transformation Grammar of Housing Units in Irbid Refugee Camp

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Abstract. This paper presents research on the design challenges in refugee camps where "temporary" shelters often evolve into permanent homes and larger communities. These transformations convey an informal design process, a phenomenon evident in Irbid Camp for Palestinian refugees in Jordan. To study this site and design process in detail, shape rules based on the transformation of ten individual housing units are developed, with consideration of area and growth limitations inside the refugee camp. The Irbid Camp Grammar reveals a modular, grid-based logic at play in the incremental and spontaneous design of refugee housing from temporary shelters to permanent homes. This study is one step forward in helping us understand how formalizing this growth logic can contribute to the design of better emergency housing interventions in the future.

1   Background and Research Problem

More than 70 years have passed since the Arab-Israeli war in 1948. However, Palestinian refugee camps in Jordan, Palestine, Syria, and Lebanon are politically defined as "temporary settlements" today, even though those camps still exist. Following the Arab-Israeli war in 1948, Palestinian refugee camps in Jordan were first initiated as emergency settlements for exiled Palestinians. Some of the camps were installed in areas that later became neighborhood-like settlements within the urban envelope of host cities. The "temporary status" of refugee camps did not stop camp inhabitants from practicing their daily life and developing their livelihoods and physical built environments (Al Husseini, 2010; Hanafi, 2010). According to UNRWA (2021), Jordan hosts ten official camps for Palestinian refugees, accommodating nearly 370,000 Palestinian refugees, or 18 percent of the country's total. These Palestinian refugee camps are now established as permanent

neighborhood-like settlements within their host cities. The ten camps in Jordan evolved through a long process of incremental transformations from their initial state as emergency settlements to their current state as permanent neighborhood-like communities (Abu-Aridah, 2016).

To analyze and understand the design challenges of emergency housing interventions and their long-term implications, this research studies the transformation of individual refugee housing units in Jordan using shape grammars. More specifically, the focus is on ten houses from the Irbid Camp, which is one of the ten camps for Palestinian refugees in Jordan that has evolved into a permanent community over the last 70 years. The Irbid Camp grammar interprets the transformation of the housing units in abstracted two-dimensional plan and three-dimensional massing representations that convey the major spatial relationships that evolve from one phase of informal development to another.

The major research questions shaping this work are: (1) how can shape rules documenting spatial relations and their change over time help designers understand the informal transformation process of housing units in Irbid Camp; and (2) how the formal interpretation of these design moves might help progress the design of emergency housing interventions in the future.

2 Methodology

2.1 Shape Grammars

Shape grammars are a rule-based formalism characterized by visual computations that was first launched by Stiny and Gips in 1972. The primitives in shape grammars are shapes rather than symbols, and the relationships and operations on shapes are all spatial rather than symbolic. Therefore, shape grammars use rules that are shape specific rather than property specific, allowing designers to describe, interpret, and evaluate spatial relationships with geometric algorithms (Gips, 1999; Stiny & Gips, 1972).

Shape grammars can be broadly divided into two categories: analytical grammars that are developed to analyze existing designs and original grammars that are concerned with the creation of new and original designs (Colakoglu (2005). This work is concerned primarily with analysis and how that analysis can inform future designs. To that end, transformation grammars specified with parametric shape rules are used to study the informal design of housing units in the Irbid Camp. Transformation grammars are a unique class of grammars focused on how languages of designs change over time or from one language to another (Knight, 2014; Knight, 1994). Parametric shape rules use parametric shapes to formalize rules that can adapt to a range of possible geometries and related constraints as specified in the rule (Stiny, 1980).

2.2   The Case Study: Irbid Camp for Palestinian Refugees

The Irbid camp for Palestinian refugees is in the downtown area of Irbid city, north of Jordan. The camp was set up in 1951 on an area of 0.24 square kilometers. Fig. 1 shows the aerial image of the camp two years after its establishment (left) and a second aerial image of the current situation of the camp (right). The camp originally housed 4,000 refugees in emergency tents that were set up on 8x8 meter land plots. The camp now houses more than 28,000 registered Palestine refugees (UNRWA, 2021).

Fig. 1. Aerial Photo for Irbid Camp in 1953 and 2016 (Image by Author)

The primary data used for this research was collected to explore the patterns of physical and socioeconomic integration of the two major Palestinian refugee camps in Irbid city in Jordan (Abu-Aridah, 2016). The refugee housing units in Irbid Camp have gone through many alterations and replacements during the 70 years of the camp's existence (Abu-Aridah, 2016; UNRWA, 2021). Based on the categorization of shelter types by IFRC (2013), the following transformation stages of the refugee housing units in Irbid camp are defined (as illustrated in fig. 2):

- **The emergency phase:** this phase comprised the setup of tents on 8x8 meter land plots that were assigned to refugees upon their arrival at the camp.
- **The temporary phase:** this phase witnessed the building of one room using temporary building materials of mud block and bamboo.
- **The transitional phase:** In this phase, refugees added kitchens and toilets to the initial rooms that were built during the temporary phase.
- **The core unit phase:** during this phase, some refugees demolished the residential units that were built during the temporary and transitional phases and replaced them with permanent building materials, and illegally enlarged their land plots by occupying parts of the adjacent streets. Other refugees added extra rooms to their residential units without destructing the rooms that were built using mud blocks and bamboo.

- **The vertical expansion phase:** this phase documents the evolution to a more permanent housing construction as some refugees added extra floors to their core units.
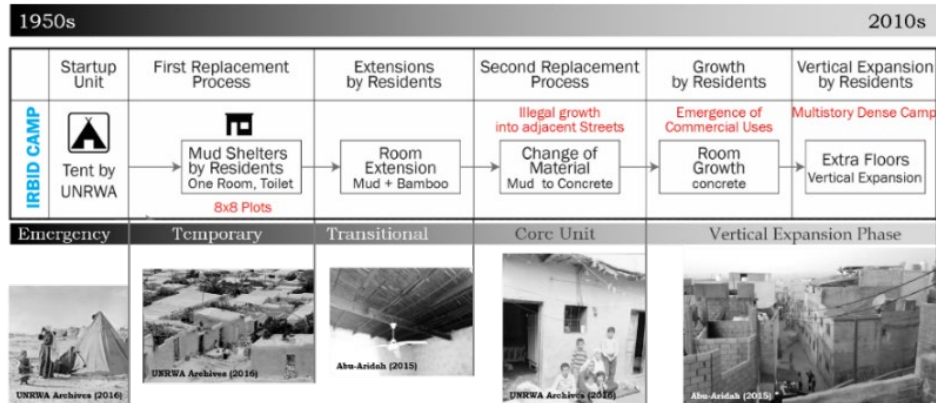

Fig. 2. Transformation of Housing Units in Irbid Camp (Image by Author)
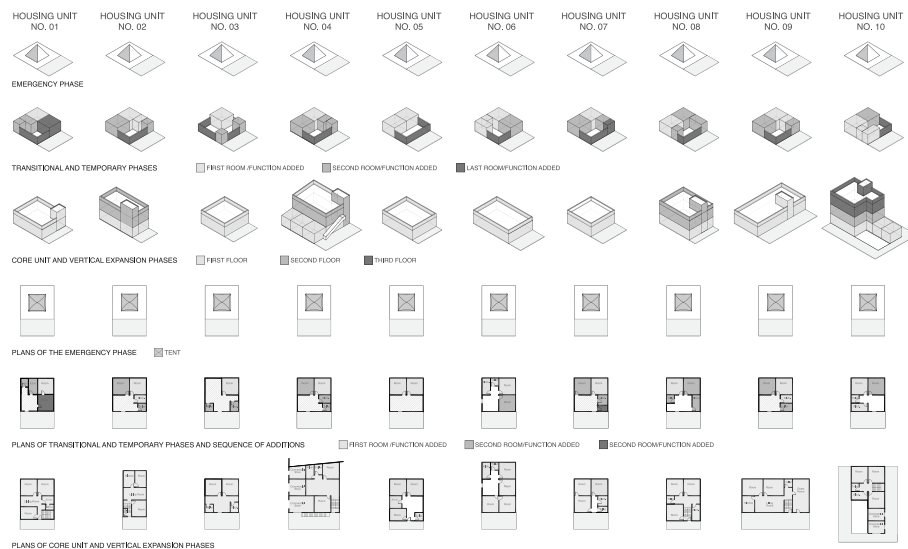

Fig. 3 Housing Units 1 – 10 (Image by Author)

The housing units selected for the scope of this study belong to key residents and informants who settled in Irbid camp from the early years of its establishment and performed significant transformations in their residential units since then. This base corpus consists of ten housing units which are illustrated in detail in Fig. 3. This figure depicts the transformation process for each of these units over all five phases in two-dimensional plans and an overall three-dimensional massing. The ten housing units all started as a

small tent. They each maintained a single-story, rectilinear enclosure limited by their land plot during the transitional and temporary phases, which is associated with having smaller households at the beginning that maintained a similar character within the camp community. During these two stages, housing units were composed of basic living spaces including bedrooms, kitchens, and toilets. However, each housing unit evolved in a very different way when the households started to grow, adding more spaces to suit their unique social and economic needs, such as guest rooms, commercial shops, and gathering areas.

3 The Irbid Camp Grammar

The Irbid Camp Grammar is a transformation grammar developed to analyze and explain the informal transformation of refugee housing units. The grammar interprets this process in five transformation stages, each related to a specific phase of development in the refugee settlement discussed in the previous section. These transformation stages are each defined with parametric shape rules to develop an understanding of how the designs change from one phase of the settlement to the next (Knight, 2014; Knight, 1994; Stiny, 2006). The research builds on the existing knowledge of the Irbid Camp and provides a visual analysis and generative specification to formalize the transformation of the refugee housing units over their 70-year existence.

The creation of the Irbid Camp Grammar encompasses the following steps: (1) analyze the spatial layouts and relationships of the ten existing housing units as they evolved from their initial conditions to their current design; (2) define a shape vocabulary that the houses and their transformations can be described with; (3) design a parametric rule set to describe the transformations of the housing units step by step; and (4) apply the rules to generate a sample design to test the validity of the grammar.

3.1 Analysis of Spatial Relationships of the Housing Units

To analyze the corpus of houses in each phase of the transformation process, a tree diagram is developed (Fig. 4). The tree diagram serves several purposes: (1) to depict primary spatial relations for the selected cases, (2) to establish a shape vocabulary that can be used in the shape rules, and (3) to synchronize the growth and transformation of refugees' housing units with the growth phases of the camp as a settlement. The tree diagram reveals many common features between the examined housing units that informed the design of the shape rules, especially during the emergency and the temporary phases. The ten housing units evolved from three basic layouts that are illustrated in the temporary phase. The transitional phase also demonstrated functional and organizational similarities. During this phase,

kitchens, and toilets were the two main spaces that are added to the original layout, but with different locations and sizes. The core unit and the vertical expansion phases introduce the addition of more functions and spaces in a modular way. This analysis shows how the aggregation of spaces in each phase follows an informal grid-like organization, based on each new space relating to the previous construction. This incremental logic inspired the creation of a flexible yet modular parametric shape grammar to further interpret this design process.

Fig. 4 Tree Diagram showing the evolution of ten housing units at Irbid Camp
(Image by Author)

3.2 Definition of Shape Vocabulary

The primary shape vocabulary of the Irbid Camp Grammar, illustrated in Fig. 5, is developed based on the analysis of the plans' spatial elements that are extracted from the tree diagram. The shape vocabulary consists of polygons that represent the spatial functions in the refugees' housing units at any phase of the transformation process. From top left in the figure, the largest shape is the plot (PL), which specifies the boundary given for each housing unit. Moving to the right, the next shape is the tent (TN), other shapes in the top of the figure represent the primary spatial functions that were added during the temporary and transitional phases, including rooms (R), toilet (T), kitchen (K), and yards (Y). The shapes in the bottom of the figure represent the spatial functions added to the housing units during the core unit and

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vertical expansion phases including the staircase (ST), living room (LR), commercial store/shop (CS), hallway (H), and guest room (GR).


Fig. 5 Shape vocabulary elements of the Irbid Camp Grammar (Image by Author)

3.3   Shape Rule Design

The shape rules of the Irbid Camp Grammar are parametric shape rules describing spatial relations of the refugee housing in terms of transformable polygons. A limited number of rules are represented using rule schemata to capture emergent variability that follows a clear logic but resists the definition of a parametric shape rule (Economou & Kotsopoulos, 2015; Ligler & Economou, 2018; Stiny, 2006). Key conventions used in the grammar include parameters and labels. Labels are used in the graphic definition of rules to contextualize and control the application of rules. For example, the rule in Fig. 6 shows a dot label which orients the addition of the new shape to the top right of the initial shape. Parameters are used to indicate the height and width of each function in the housing unit and are also used to indicate the position of each added function with reference to a previously added function. Dashed lines are used to help illustrate the spatial relations of each newly added function, and the determining distances are defined as parameters as illustrated in Fig. 6. For example, the width of a room is indicated using the parameter Xr and the height is indicated using the parameter Yr. The horizontal distance between each added function and the previously added function is indicated using the parameter Xn and the vertical distance is indicated using the parameter Yn. When applying these rules, the designer specifies the values of these variables to ensure the proper application of each rule.   Similar parameters are defined for all shape rules described hereafter.
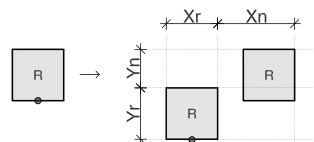

Fig. 6 Parametric Definition and Position of Functions (Image by Author)

Rule schemata are also utilized in the grammar to specify rules using irregular polygons that result from the cumulative relations of the regular polygons of the shape vocabulary. For example, the rule that defines the internal court is presented in rule schemata as shown in Fig. 7.
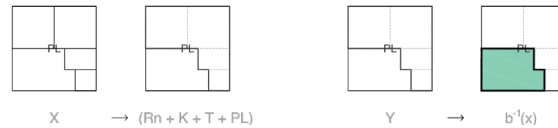

$$X \quad \rightarrow \quad (Rn + K + T + PL) \qquad Y \quad \rightarrow \quad b^{-1}(x)$$

Fig. **7** Example of Applying Rule Schemata (Image by Author)

The first part of the rule represents the Boolean union of the shapes that are formed by rooms, kitchens, and toilets, the Boolean union of those shapes is indicated as (X) while the second part of the rules, indicated as (Y), represents the inverse boundary of the shape (X) with reference to the plot boundary.

The Irbid Camp Grammar includes 32 parametric shape rules in five stages. Each rule defines a new function, determines the dimensions of that new function with specific parameters, and adds it to the existing spatial form that is generated through the sequential application of rules for each housing unit.

The five transformation phases and associated rules include:

Phase (1) is the emergency phase and the starting phase (rules 0 to 1.2). This phase includes three rules that represent the assignment of a fixed 8x8 meter land plot, setting up the emergency 4x4-meter tent, and removing the tent at a later stage as shown in Fig. 8.
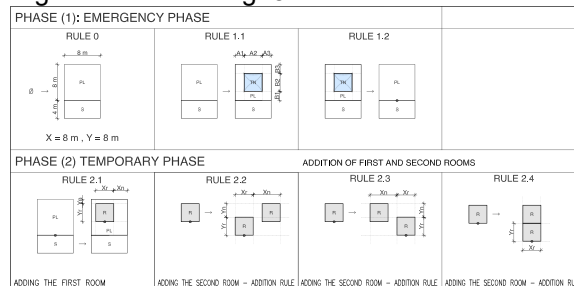

Fig. 8 Shape Rules for Phase (1) and Phase (2) (Image by Author)

Phase (2) is the temporary phase (rules 2.1 to 2.4). This phase describes the process of building one room and adding another room using temporary building materials. This stage is represented using four rules in which the first one (rule 2.1) defines the first room, its height, and width and determines its position within the land plot. The remaining rules represent the addition of the second room and determine its spatial relationship with the first room (Fig. 8).
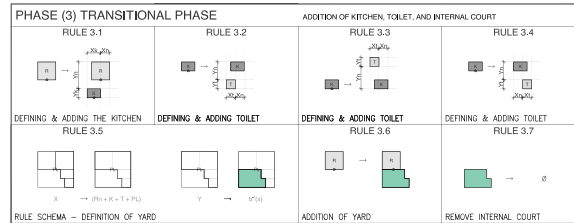
Fig. 9 Shape Rules for Phase (3 (Image by Author)

Phase (3) is the transitional phase, which is a continuation of the temporary phase (rules 3.1 to 3.7). This phase includes the addition of the basic functions of kitchens and toilets and the definition of the internal yard as the remaining space within the plot boundary after adding the kitchen and toilet functions. This phase is described in seven rules. The first rule of this phase is used to define the kitchen (rule 3.1). The next three rules represent the addition of the toilet, its location, and dimensions with reference to the kitchen (rules 3.2, 3.3, 3.4). Two rule schemata are defined to add the internal courtyard (rules 3.5, 3.6) and one more rule is defined to remove this courtyard (rule 3.7). All rules for this phase are illustrated in Fig. 9.
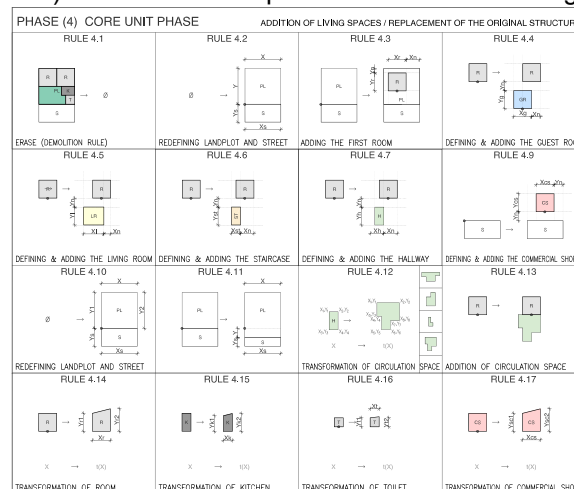

Fig. 10 Shape Rules for Phase (3) (Image by Author)

Phase (4) is the core unit phase (rules 4.1 to 4.17). This phase describes the definition of new functions and in some cases the replacement of some housing units that were built up to the end the transitional phase. This phase includes 17 shape rules which are shown in Fig. 10. Rule 4.1 indicates the demolition of the housing unit entirely. Rules 4.2 and 4.10 indicates the definition of the land plot with parameters to represent the expansion of the original land plot that was performed by some refugees as described earlier in

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this article. Rule 4.11 is used to indicate the expansion of the original plot in one or two dimensions without demolishing the original housing unit.

Rule 4.3 is used to define the first room that is added after the destruction of the original housing unit, it defines the room's height and width and determines its position within the land plot. Rules 4.4 to 4.9 define the functions of the guest room, living room, staircase, hallway, and commercial shop, respectively. Rule 4.12 is a rule schema that represents the transformation of the shape that indicates the hallway, and rule 4.13 determines the position of the hallway that is generated using rule 4.12. Rules 4.14 to 4.17 are also rule schemata that indicate the transformation of the shapes of the room, toilet, kitchen, and commercial shop functions.

Phase (5) is the vertical expansion phase or permanent housing phase, consisting of rules 5.1 to 5.3. This phase represents the addition of extra floors which can be found in some housing units inside the camp. This phase includes three shape rules. The first rule (rule 5.1) defines the shape transformation from 2D to 3D, the second rule (rule 5.2) represents the addition of the second floor as a typical one, and the third rule (rule 5.3) presents the addition of the third floor as a typical floor as well. All rules for this phase are illustrated in Fig. 11.
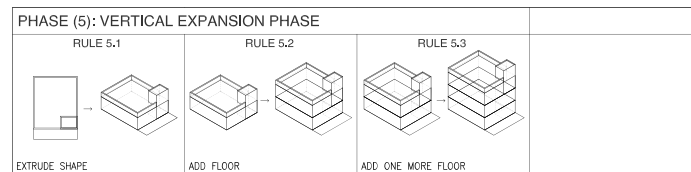

Fig. 11 Shape Rules for Phase (5) (Image by Author)

3.4 Generating Irbid Camp Designs

To further articulate the Irbid Camp grammar, a derivation showing the detailed application of shape rules to generate housing unit no. 02 from its temporary state to its current state is illustrated in Fig. 12. The following rules are applied to produce this design: starting from rule 0 in the emergency phase, a 4x4 meter tent (rule 1.1) was placed in the center of the 8x8 meter original plot, and the tent was removed using rule 1.2. Moving to the temporary phase, one room was added to the upper right side of the land plot using rule 2.1 and a second room was added next to the first room using rule 2.2. The values of all parameters for these rule applications are shown in Fig. 12.

In the transitional phase, rule 3.1 is applied to add the kitchen, rule 3.2 is used to add the toilet, and rules 3.5 and 3.6 define the internal courtyard. This housing unit was demolished after the transitional phase and the dimensions of the land plot are changed. Refugees claimed the extra space by expanding into the adjacent streets. Thus, for the core unit phase, rule 4.1 is applied to

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demolish the housing unit entirely and rule 4.2 is applied to reshape the land plot which became 11 meters in height and 5.5 in width. Rule 4.3 is applied to add the first permanent room of concrete. Rule 3.1 is applied to add the kitchen and rule 3.4 is applied to add the toilet, which happened to be below the staircase. Rule 4.4 is applied to add the guest room and rule 4.6 is applied to add the staircase. Then, rule 4.5 is applied to add to the living room. In the vertical expansion phase, rule 5.1 transforms the two-dimensional layout to a three-dimensional representation. Rule 5.2 is applied to add a second typical floor based on the layout of the lower level.
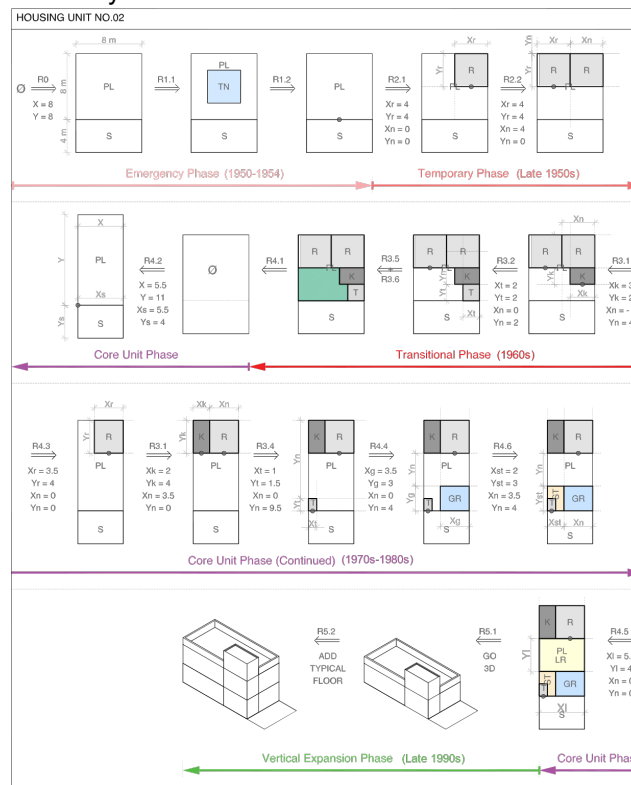

Fig. 12 Application of Shape Rules for Housing Unit No.2 (Image by Author)

4   Findings and Conclusions

The parametric shape grammar presented in this paper interprets the long-term transformation process of refugee housing at Irbid Camp as a series of design modifications. Parametric shape rules are specified to formalize the spontaneous growth and transformation of ten housing units over time. The rules foreground the modular-like evolution of the houses that were originally

achieved informally as a self-build process unique to each refugee housing unit. The rules also demonstrate a correlation between the growth phases and the evolving spatial configuration of the housing unit. The clarification of the modular growth system suggests the opportunity for further interventions in refugee housing design to mediate these transformations and utilize the grammar as a basis for responding to housing emergencies with design solutions that acknowledge the potential permanence of the community. The Irbid Camp Grammar provides a basis for designing these new strategies, focusing on the concepts of flexibility, adaptation, and modularity to anticipate the self-build process. Learning from the Irbid Camp Grammar, future work will aim to investigate the social and economic aspects that impacted each phase of the camps' growth and to develop a computational model that can be further utilized in designing refugee housing systems for different locations and geographies.

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