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Implementing Shape Grammar to Generate New Façades Based on the Historic Façades of Iconic Buildings on Naser-Khosrow Street in Tehran

Niloofar Zolghadrasli, Eduardo Costa and Mahyar Hadighi

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Abstract:

A methodology for designing new structures and reinvigorating existing buildings in keeping with a historic urban area is presented. The proposed approach draws on Hadighi and Duarte's (2019, 2020) systematic methodology for analyzing and creating hybrid architectural design developed based in part on comparisons between distinctive architectural examples to verify their hybrid expression of European modernism and traditional American style. In the present paper, their methodology is further developed to create hybrid designs for potential use in historic urban contexts. The proposed methodology is developed and explored in relation to Naser-Khosrow Street, a historical axis of Iran's capital, Tehran, as the focal area.

The literature includes studies demonstrating that the shape grammar methodology can be used to analyze existing traditional urban textures. However, in the present paper, shape grammar is introduced as a productive and practical tool for encoding the architectural characteristics of three significant urban façades on a focal street, referred to as the grammar corpus. To define the design language of selected buildings, designers can apply a computational design method capable of generating new façade layouts based on extracted grammars. On this basis, the shape grammar methodology is expanded to create new buildings and reinvigorate existing structures in a traditional urban context in ways that are compatible with and possibly even exemplify the characteristic features of the contextual urban space.

Keywords: Shape grammar, Urban heritage; Historic context, Generating harmony, Naser-Khosrow Street, Façade design.

1 Introduction

Historical façades contribute greatly to a city's image and, therefore, play a key role in expressing the traditional spirit of an urban space (Askari, 2009). Thus, it is essential to take into consideration that buildings, particularly in historical settings, should be designed with reference to the existing building façades in the context. From this point of view, disconformity between façades is not aesthetically pleasing and has the potential to disrupt the traditional character of urban space new constructions such that new façades should be compatible with the façades of the surrounding area. According to Fathi and Heidari, (2018), the façades of recently constructed buildings in Tehran are not compatible with the urban texture of the city. Given this background, three façades

of Naser-Khosrow Street, an important commercial and historic street in the center of Tehran, are explored as the focal corpus of the present research. The aim is to demonstrate a technique that can aid architects in taking context into account in their designs whether in regard to creating new buildings or repurposing, renovating, or otherwise modifying existing structures.

At its foundation, the design process is based on the design state a designer decides to follow in pursuing and executing a project (Pauwels et al., 2015). In working toward a final design, a designer may engage in a reframing process, evaluating various design states over time until the best design solution emerges (Cross, 1982; Schön, 1983). Thus, multiple designs may be produced and evaluated before a final version is determined. Yet, these traditional methods may not be ideal for such cases, as these frameworks are not suitable for evaluating a large number of designs (Duarte & Correia, 2006).

The potential gap between the existing context and a new design points to the need for a technique that facilitates the evaluation of possible alternatives for urban texture. Alternatively, one can implement a grammar method instead—that is, an approach in which the elements of a composition are placed according to a predetermined set of rules (Teboul et al., 2011). As a result, grammars can play a pivotal role in identifying the structural pattern of a given composition. In the process of project design, many drafts may be produced and evaluated through what can be a time-consuming process until the designer arrives at the final layout. Through a framework that paves the way for creating the best design solutions, multiple kinds of grammars can improve this process, including graph (Pauwels et al., 2015), programming, designing, discursive (Stouffs, 2015) and color grammars (Knight, 1989). However, most relevant to the present study is the shape grammar methodology introduced by Hadighi and Duarte (2019, 2020) to create architectural hybridity. Accordingly, shape grammar is proposed to create new buildings in the traditional urban context of Naser-Khosrow Street in ways that are compatible with the characteristic features of the contextual urban space.

1.1 Shape grammar

Shape grammar specifies the process of shape transformations in a recursive way (Gu & Behbahani, 2018). These transformations may consist of several steps that are repeated recursively to transform the initial shape into a terminal one (Chakrabarti et al., 2011; Cross, 1982). In each step, a finite rule—i.e., addition, subtraction, substitution, division, or modification—is applied to the considered shape—in essence, converting a left-hand-side shape (LHS) into a right-hand-side shape (RHS) (Gu & Behbahani, 2018; Teboul et al., 2011).

Through the last four decades, shape grammars have gradually evolved into a valuable tool for many fields of study (Granadeiro et al., 2013), such as painting (Stiny & Gips, 1971; Gips, 1999), product design (Trescak et al., 2009; Gips, 1999), animation (Chau et al., 2004), and computer games, simulations, and movies (Preda et al., 2005). They have also become important in architecture (Stiny & Mitchell, 1978; Gips, 1999), including in terms of analyzing existing traditional urban textures. For example, Duarte and Rocha (2006) captured the characteristic features of the Medina of Marrakech in

Morocco through shape grammar whereas Barros et al. (2013) used the methodology in relation to the structure of Mapotus's slums to establish an adaptive model. Further, Verniz and Duarte (2017) described the complex urban structures of Santa Marta, Brazil, by developing a shape grammar.

1.2 Naser-Khosrow Street Case Study

Naser-Khosrow Street is an urban heritage axis of the city of Tehran, Iran's capital, comprising iconic buildings such as Darolfonon, Shams-Ol-Emareh, and Saraye Roshan. These buildings express a turning point in the history of Iranian architecture, mainly because they represent a fusion of European and Iranian traditional styles (Diba & Dehbashi, 2004). Darolfonon and Shams-Ol-Emareh are built in the Naseri Period of Iran when Naseredin Shah was the Ruler of Iran. Darolfonon is built in 1852 and is considered the first school of Iran. Shams-Ol-Emareh was built in 1863, and it is well known because of its height. And the other building, Saraye Roshan is built in 1894 in the period of the First Pahlavi. This building is a reminder of the Gothic period because of its adoration. In general, the façades of recently constructed buildings in Tehran are not fully compatible with the urban texture of the city (Sattarzad Fathi & Heidari, 2018). This is especially the case in the Naser-Khosrow area. Therefore, the outstanding façades of these three iconic buildings on Naser-Khosrow Street are the subject of this paper, as they offer set of specified design instances characterized by styles that can be encoded in a shape grammar (Gu & Behbahani, 2018).

Figure 1 shows the locations of these buildings on the street. In chronological order of construction, Darolfonon, Shams-Ol-Emareh, and Saraye Roshan constitute the corpus of this research.

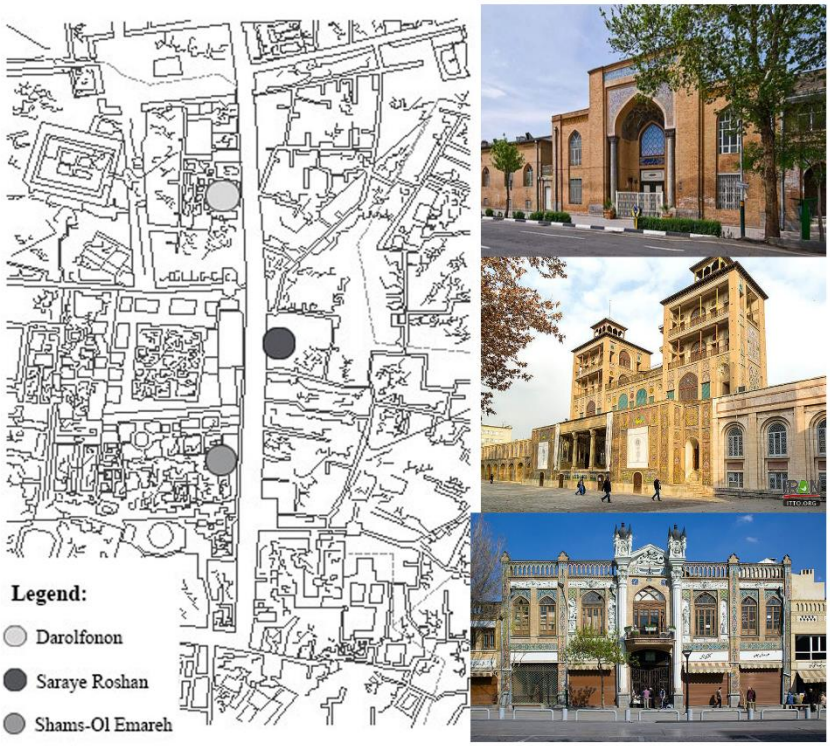

Fig. 1. The left hand side shows the location of corpora in the Naser-Khosrow Street, Theran, Iran. And the right hand side of the image from top to bottom shows Darolfonon, Shams-Ol-Emareh and Saraye Roshan respectively.

Location of corpus in the Naser-Khosrow Street, Tehran, Iran

2 Methodology

This paper is part of a more extensive study undertaken using shape grammar to redesign building façades in the historical street of Naser-Khosrow. The more extensive research is based around six steps: (1) studying Naser-Khosrow Street as the urban heritage context; (2) identifying iconic buildings on the street; (3) introducing an impaired façade located on Naser-Khosrow Street; (4) capturing the grammars of iconic buildings in the context; (5) developing the captured grammars; (6) and proposing a grammar framework based on the historical context of the impaired façade. The present paper focuses on capturing the frameworks of significant buildings on Naser-Khosrow Street as a foundation for creating new designs based on the given corpus (Gero, 2006). Generally, the proposed framework is created through two major steps: (1) extracting rules from the corpus, which results in a descriptive grammar (Ahmad & Chase, 2004), and

(2) generating new design solutions, which are referred to as a prescriptive grammar(Ahmad & Chase, 2004). Following the idea of transformation in design (Knight, 1983), influences of historical architecture on local architecture (Coutinho et al., 2011) and hybridity in architectural design (Hadighi & Duarte, 2018), this paper focuses on generating new design solutions based on historical examples.

2.1 Extracting rules from a corpus

According to Stiny (1985, 1977), the process of extracting rules can be extracted from a corpus through the use of a parametric shape grammar. This method is defined as a tuple with five elements {V, L, P, I, R} corresponding to vocabulary, labels, parameters, initial shape, and rules, respectively. To simplify the process of defining the vocabulary, i.e., a finite collection of shapes and elements of the shape grammar are abstracted (Mitchell et al., 1991, p. 19), whereas slight differences between shapes are eliminated (Ahmad & Chase, 2004). The labels or symbols are assigned to each shape to include each vocabulary element in the grammar. Measurements of each item in the vocabulary are defined by parameters that provide flexibility for defining the grammar (Chen, 2005, p. 78). The initial shape or axiom serves as the starting point of the process (Stiny, 1980). Described in a schema of $A \rightarrow B$, the shape grammar rules apply to vocabulary elements in terms of transforming a left-hand-side (LHS) A into a right-hand-side (RHS) B (Pauwels et al., 2015).

A shape grammar is usually built on two sets of principles—a lower-level grammar and a higher-level grammar—through a process of inference (Barrios, 2005). In the first stage of the process, the rules are applied recursively or in a parallel way to the initial shape in order to determine the fundamental units of the façade. Defining the units of the façade's composition is the primary goal at this stage. In the next step, rules are applied to the fundamental units generated in the previous step. The purpose of these rules, which have been extracted, is to organize the composition of the façade.

The process of analyzing the facades is not confined to their geometry. In this research, factors such as building codes and cultural context were considered in with the analysis. It is important to note that the construction of Naser-Khosrow Street is regulated by a specific design guideline that prohibits buildings from exceeding two floors in height. Given that this is the case, the analysis was performed for two-story buildings such that the extracted grammars would be compatible with the code.

Further, the analysis took into account cultural context. Specifically, limitations in regard to opening type and size were observed. That is, limitation in the size of the windows that does not extend a particular size. Based on these characteristics dictated by cultural context, the openings in the analysis were grouped into distinctive categories accordingly.

Figures 2 show the facades analysis of Darolfonon, Shams-Ol-Emareh, and Sarayeh Roshan respectively.

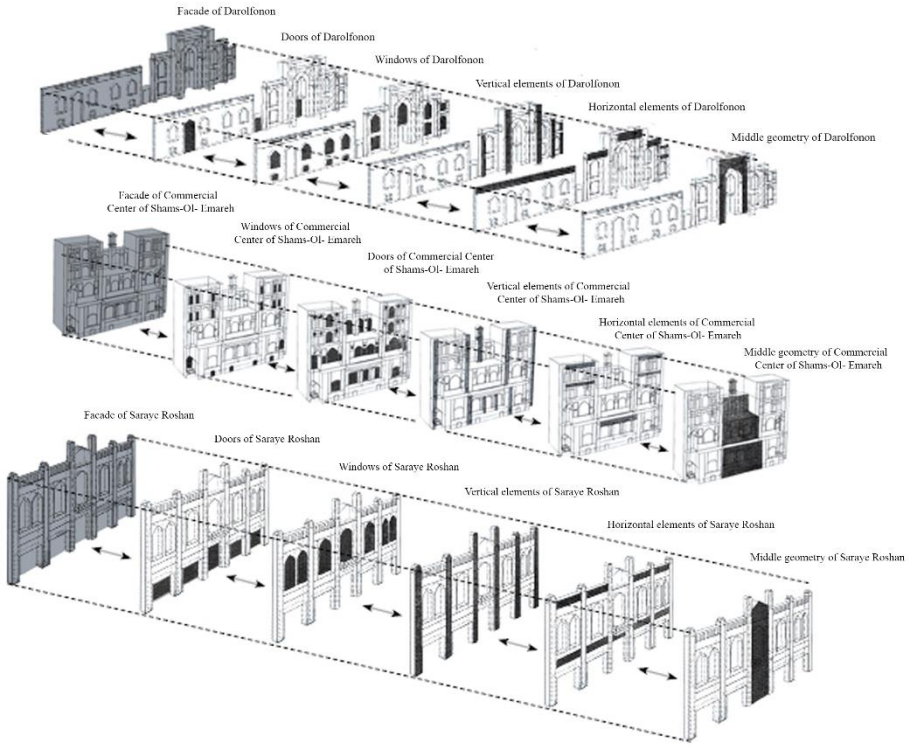

Fig. 2. Analysis of facades corpora of Darolfonon, Shams-Ol-Emareh, and Sarayeh Roshan.

2.2 Generating the design solution

The previous section provides the description of shape grammar process, which provides the basis for developing a new grammar in accordance with the traditional features of the selected design. This new grammar generates new designs through a derivation strategy (Mohamed, 2005), where the extracted rules are applied in a sequence or in a parallel way. Either process enables the designer to organize vocabularies in a composition in multiple ways and derive the solution that is most compatible with the original from among all the possible solutions.

Designs generated by this method are bound to a specific style (Chakrabarti et al., 2011). Yet, the style thus generated can correspond to the style of the extracted grammar of the corpus (e.g., Chase, 2002; Ruiz-Montiel et al., 2013) or it can be a newly defined style based on the proposed building (e.g., Knight, 1994; Moon, 2007) or it can be a hybrid of the two.

3 Results & Discussion

3.1 Rules inferred from the corpus (Stage A): Lower-level grammar

At the outset of this process, the initial shape is demonstrated through a parameterized schema. Wx and Lx indicate the width and length of the rectangle with the parameter of x, respectively (Figure 3). Note that the application of different rules to the initial shape means that the output can follow different paths (Mohamed, 2005). In the present study, each element of the corpus defines its own rules. Thus, P rules are inferred from the palace of Shams-Ol-Emareh, C rules relate to the commercial building of Saraye Roshan. Finally, S rules represent Darolfonon. The rules of each element of the corpus are defined in Figure 4.

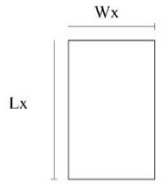

Fig. 3. Parameterized initial shape.

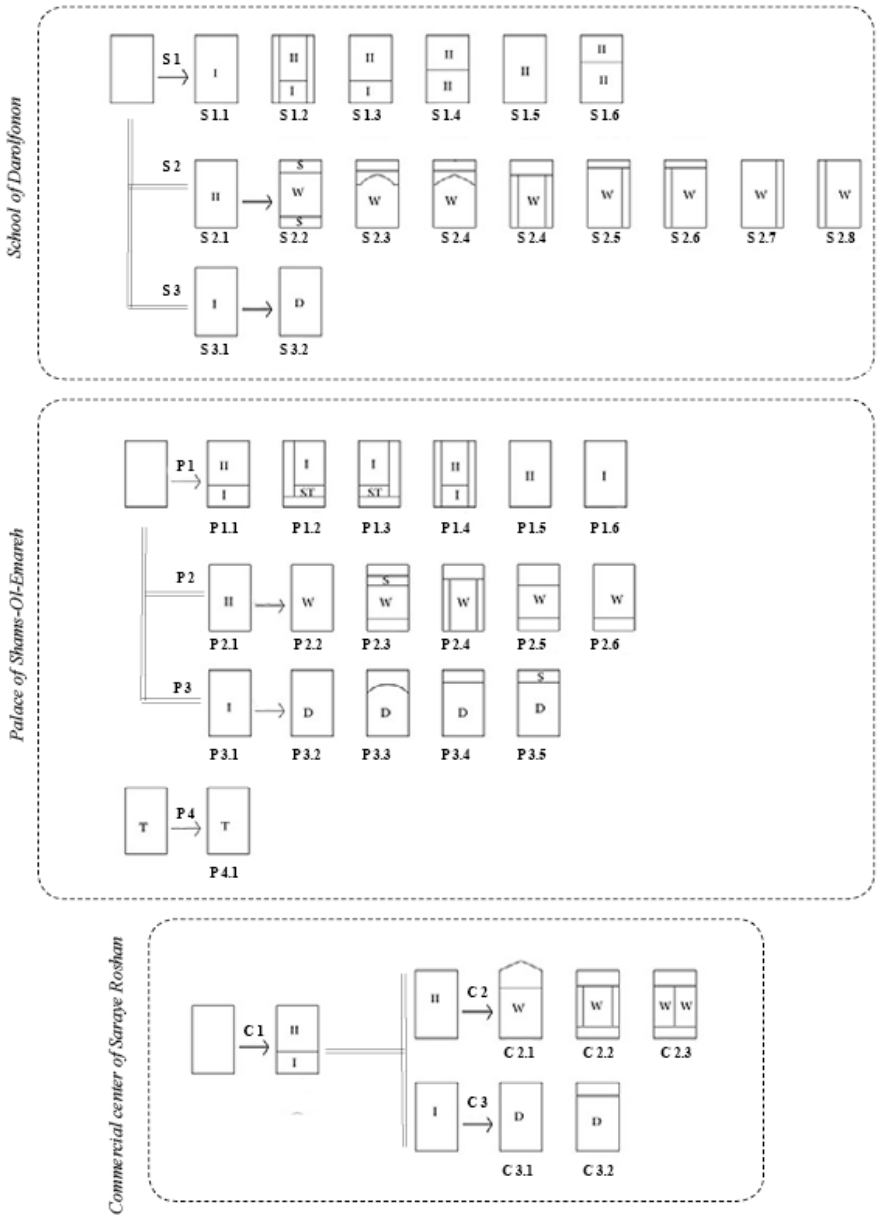

Fig. 4. Rules of stage A.

For this stage of the process used to produce the grammar, the rules present three common types of vocabularies in the defined corpus as follows:
1- Division of the floors into sets of horizontal and vertical parts
2- Definition of the vocabulary of the window openings
3- Definition of the vocabulary of the doors
With the application of rule 1 of each corpus, the ST, I, and II labels are generated from the initial shape in which ST represents the stairs, whereas I and II relate to different façade elements, which are selected according to the rules. In rule 2, II transforms into W for windows and S for small windows. And, in rule 3, I transforms into D, the label for a door and small windows above it. For Shams-Ol-Emareh, an additional rule was defined: In rule 4P, the tower was described by label T.

3.2 Rules inferred from the corpus (Stage B): Higher-level grammar

Vocabularies of this set consist of the output units of the lower-level grammar, which are labeled with distinctive colors which describe the configuration of units. In this research, the designs are extended through these steps as follows in Figure 5.

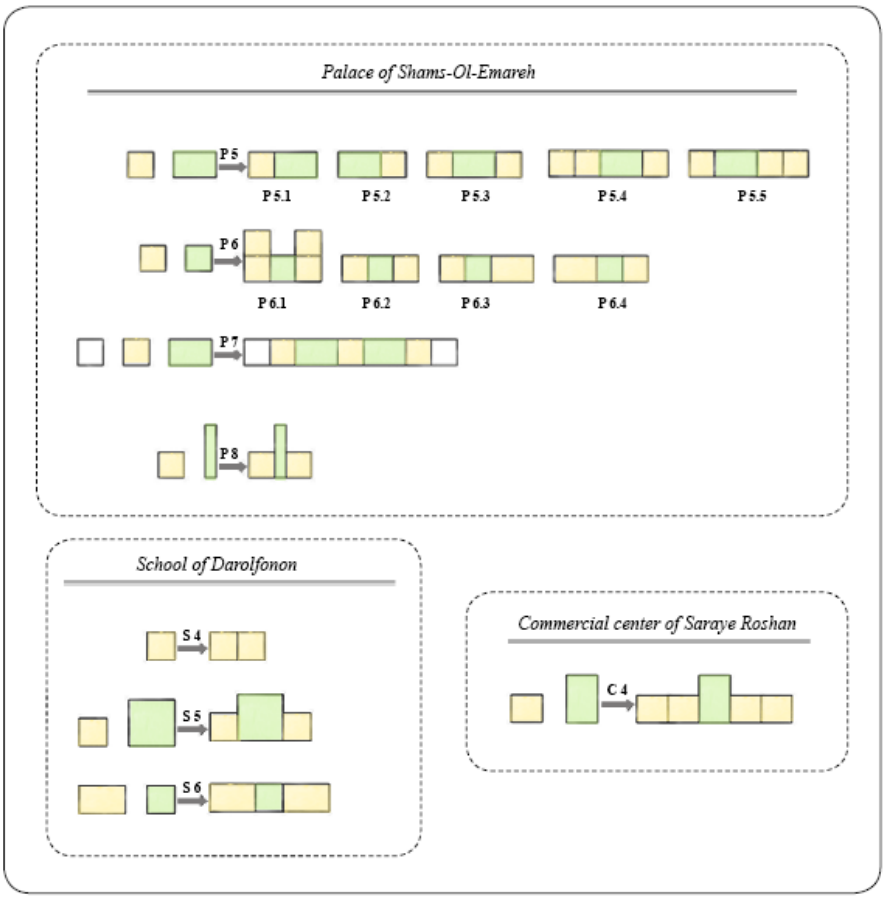

Fig. 5. Rules of stage B.

3.3 The design process for iconic buildings

The given rules cover the language design of each building such that they produce a design in keeping with that of the existing façade. Figures 6 and 7 reveal the scenario of applying rules to the composition of the façade in Saraye Roshan and Darolfonon. Shams-Ol-Emareh is a five-story building. In Figure 8, the grammar schema of the ground and first floor is demonstrated. Figure 9 illustrates the second floor. Finally, in Figure 10, the third and fourth floors are represented.

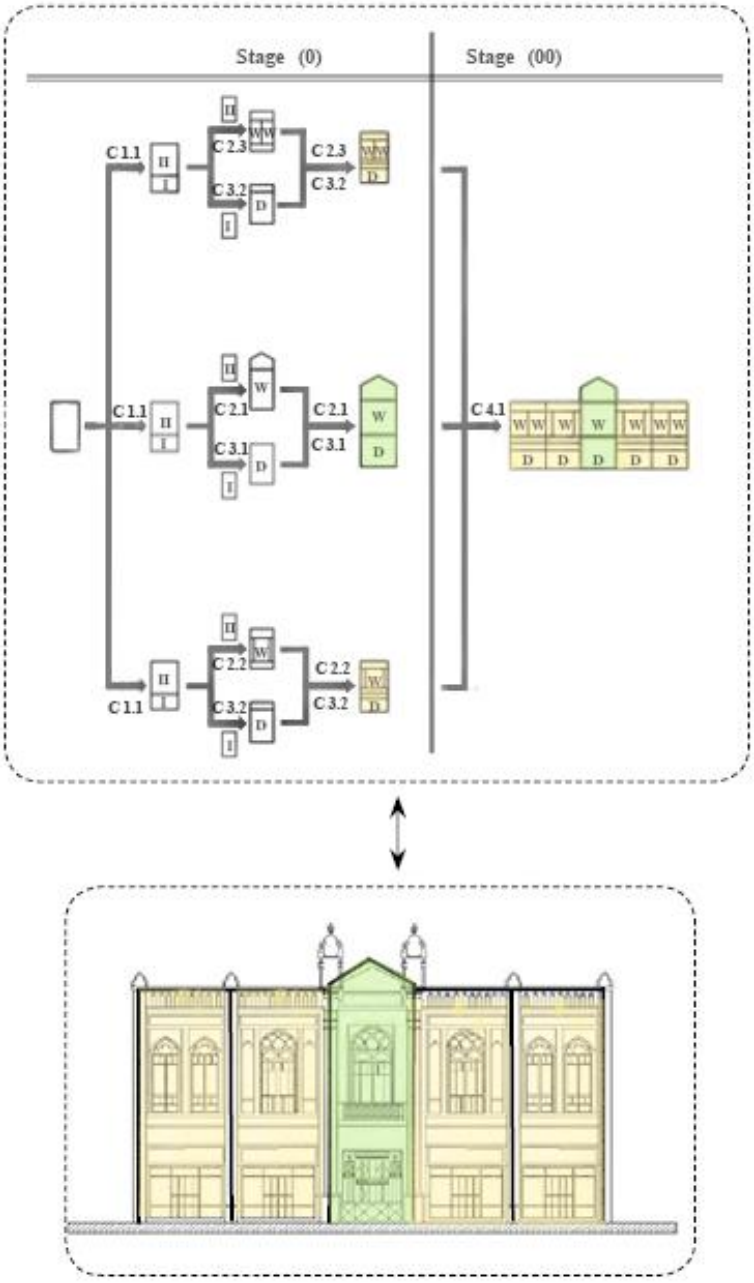

Fig. 6. Procedure of Shape grammar in Saraye Roshan

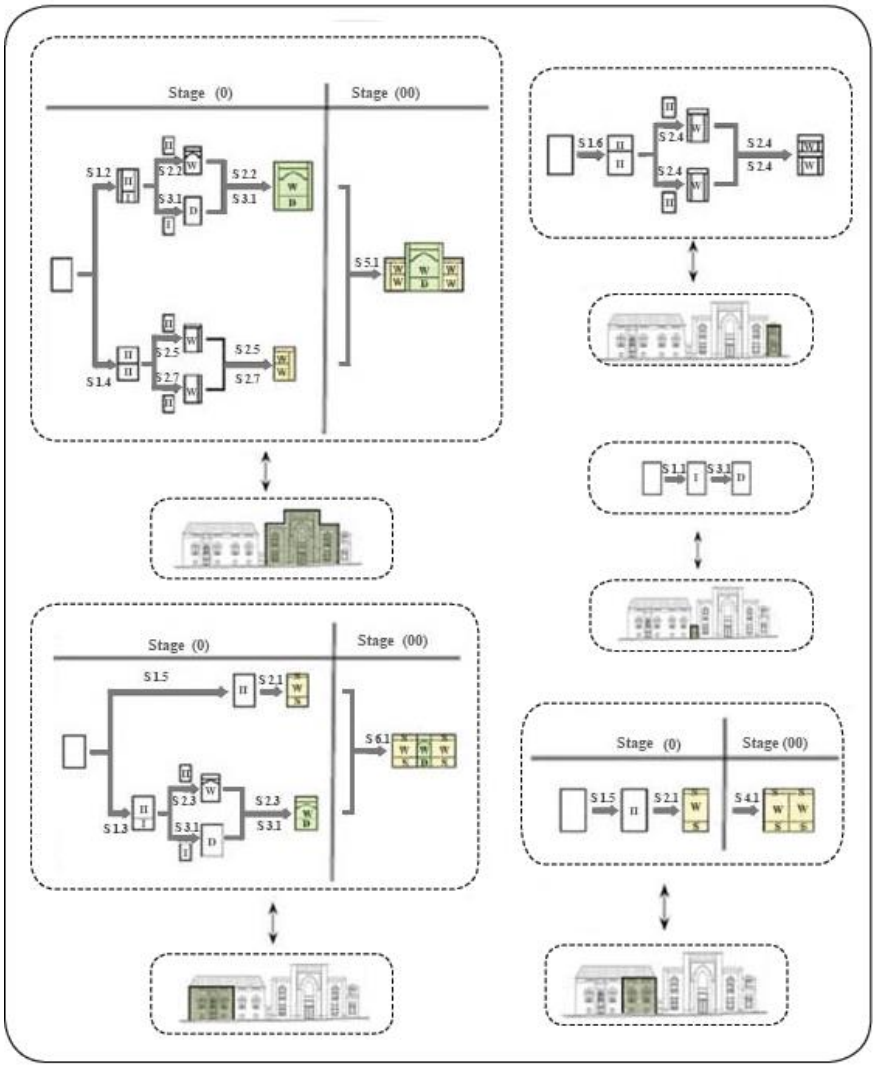

Fig. 7. Procedure of Shape grammar in Darolfonon

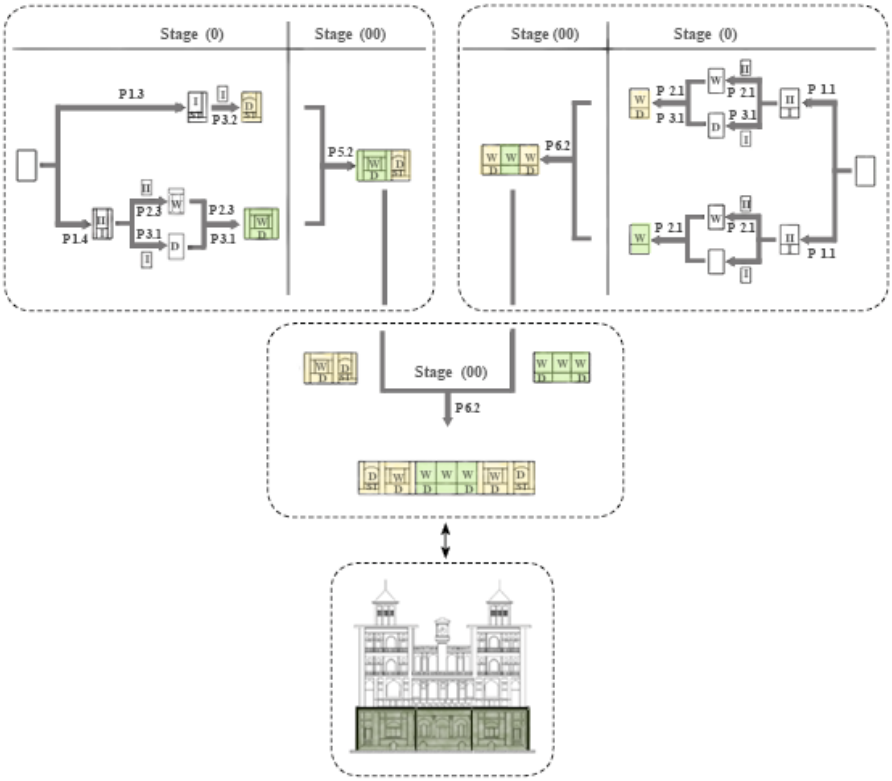

Fig. 8. Procedure of Shape grammar in ground and first floor of Shams-Ol-Emareh

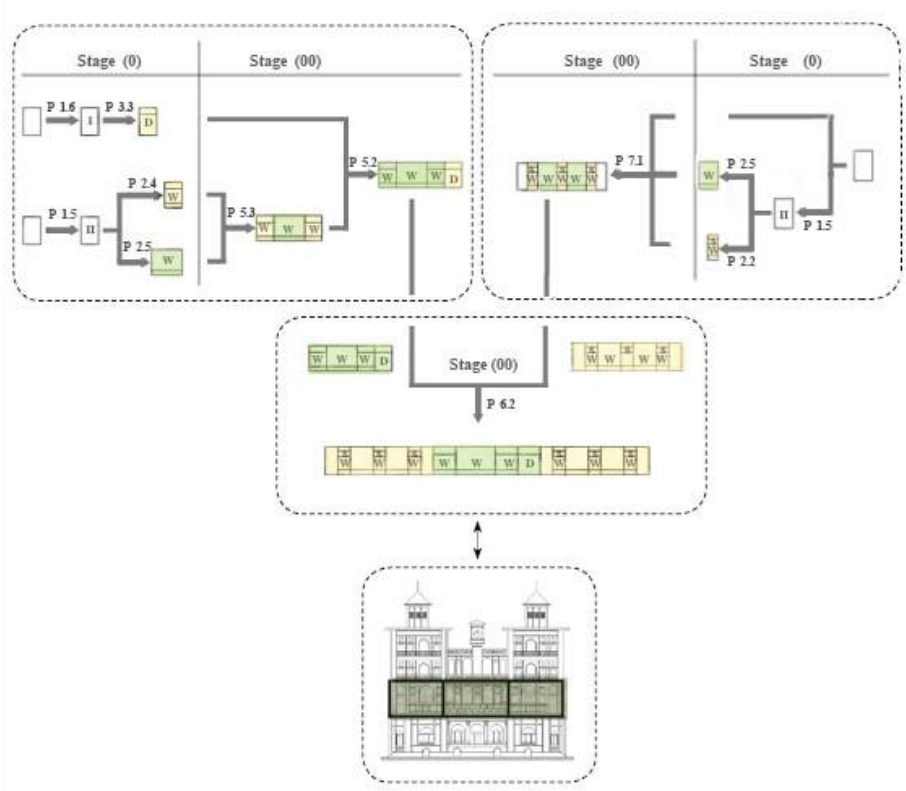

Fig. 9. Procedure of Shape grammar in second floor of Shams-Ol-Emareh.

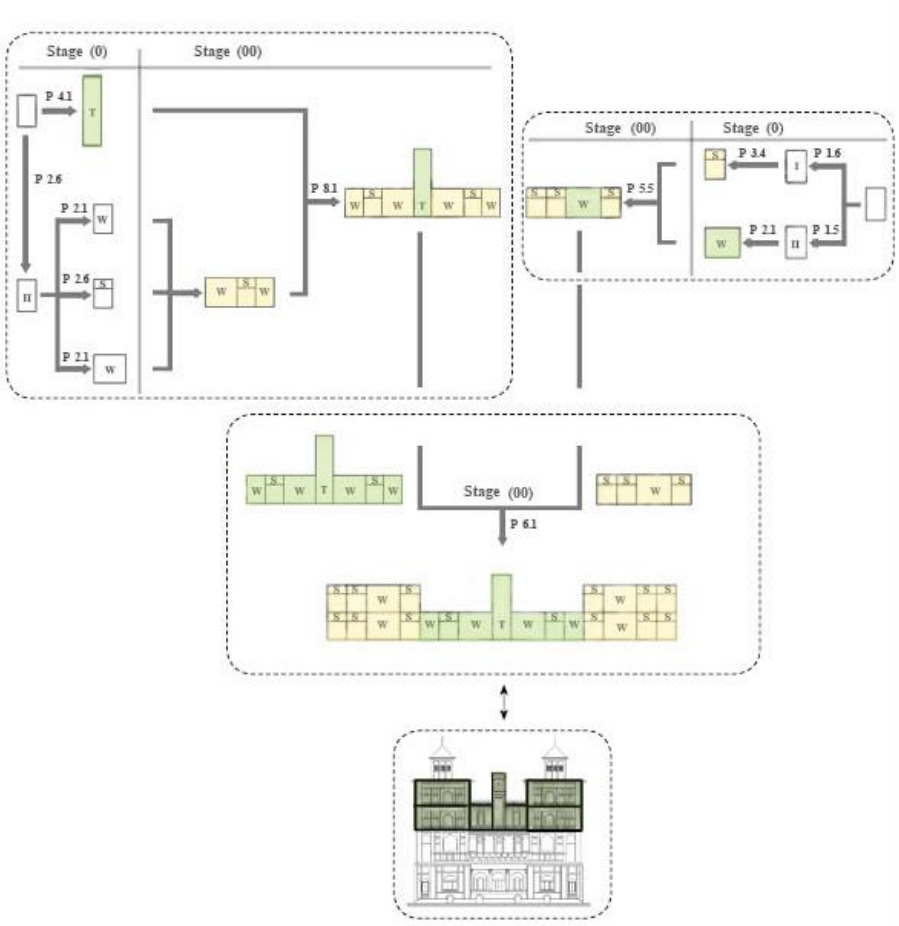

Fig. 10. Procedure of Shape grammar in third and fourth floor of Shams-Ol-Emareh

3.4 Generating new design solutions

Equipped with the shape grammar, designers can according to their design goals combine the stated schematic rules with each other to create a new design. Hence, by deriving rules from previous layouts, a designer can produce new façades.

From this point of view, possible additional designs can be produced through three sets of derivations (Figure 11):

1- Derivation of the lower-level grammar

2- Derivation of the higher-level grammar

3- Derivation of the lower-level grammar in combination with the higher-level grammar

Figure 12 shows a diverse range of possible fundamental units from the derivation of the lower-level grammar as generated through a tree diagram.

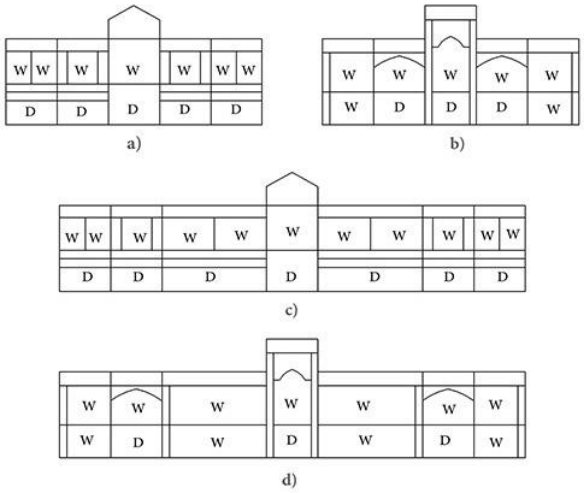

Fig. 11. a) Layout of Sareye Roshan b) Derived layout, from the lower grammar of Saraye Roshan. c) Derived layout, from higher grammar of Saraye Roshan d) Derived layout, from lower grammar and higher grammar of Saraye Roshan.

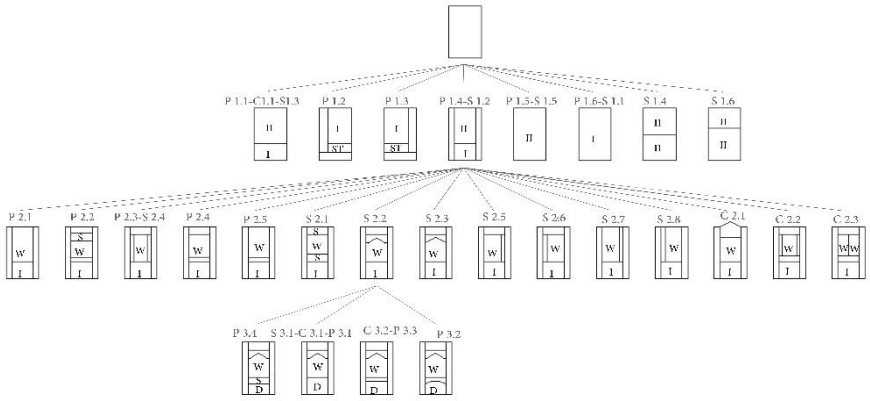

Fig. 12. Derivation tree of a fundamental unit.

4 Conclusion & Future Work

In this paper, the shape grammar methodology was used to obtain the design language of the urban façades of three buildings on Naser-Khosrow Street in Tehran, Iran.
In general, designers and architects can draw on this technique as a guide for creating hybrid architectural design in other urban areas. As such, the captured predominant features of that environment can be used as a guideline for ensuring that new buildings are compatible with the surrounding environment.
It is noteworthy that the approach presented proceeds principally according to a manual process. Forthcoming studies, with Naser-Khosrow Street as the example subject, will demonstrate how the shape grammar methodology can take into account historical aspects in relation to the needs of contemporary life without disturbing the traditional spirit of an area.

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