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RESEARCH ARTICLE

Sinan and Palladio: A comparative morphological analysis of two sacred precedents

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Received 16 November 2016; received in revised form 24 March 2017; accepted 26 March 2017

KEYWORDS

Morphosyntax;
Design precedents;
Sinan;
Palladio;
Case studies;
Süleymaniye Mosque;
Il Redentore Church;
Morphometrics

Abstract

An exploratory study on the design schemes underlying two architectural precedents is presented and discussed. The study compares the formalistic compositions of two prominent precedents on multiple levels. These levels include the morphological, semantic, and pragmatic layers. The morphological aspects of these layers are emphasized. The study aims to identify the commonalities and differences between two cases of classical sacred architecture in terms of their morphometric and morphosyntactic structures. These cases are represented by Palladio's *Il Redentore* Church and Sinan's *Süleymaniye Mosque* designs. The scope of the analysis focuses on the syntax and mathematics of the floor plans, and the facade and section of each case are referenced occasionally. Within this scope, the proportional system that regulates the compositions and eidonomy of the precedents are scrutinized. Findings resulting from the comparative analysis are reported and then discussed. The study shows that the two ostensibly different precedents share obscurely many commonalities, which are greater than what their initial appearances suggest.

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1. Introduction

Analyzing the designs of architectural precedents can be significantly informative for practitioners and educators in the field of systematic design processing. In principle, such analysis is similar to “Reverse Engineering,” where products are dismantled to infer their methods of assembly. This

method can help designers externalize and reveal design principles and style derivation rules that are typically implicit. Although the recognition of precedent-based design (PBD) as an independent systematic design methodology is relatively new (Eilouti, 2009; Moraes Zarzar and Guney, 2008), the PBD foundation as an analysis of precedents is older (Clark and Pause, 1979, 1985). Furthermore, the roots of PBD can be even traced back to Vitruvius (1999) who documented the experiences of previous architects. Within the framework of PBD studies, the area of comparative analysis has strong potential to help in the design practice

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Peer review under responsibility of Southeast University.

<http://dx.doi.org/10.1016/j.foar.2017.03.003>

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Please cite this article as: Eilouti, B., Sinan and Palladio: A comparative morphological analysis of two sacred precedents. *Frontiers of Architectural Research* (2017), <http://dx.doi.org/10.1016/j.foar.2017.03.003>

and academia. Comparative design studies are expected to contribute to the architectural design knowledge body, education, and practice. Comparative design studies can also help reveal, among others, the common design principles of buildings that belong to a given class even if they are developed in different geographic and temporal contexts.

In education, a comparative critical analysis of sets of buildings that share a typology or style represents an intellectual exercise for learners. The analysis may help in determining the rules of composition from visual or graphical representations. Examples of this are represented by precedent-based instruction (Akin, 2002) and example-based design processing (Sio and Kotovsky, 2015). In fact, the comparative visual analysis method has strong origins in art history instruction, which can be traced back to the early 20th century. An early example of this is represented by the scholarly writings of Wölfflin (1950). These writings explain how he applied this method through slide pairings of architecture and art image presentations.

In practice, an explicit system of composition may provide a clear point of departure for design conception and processing. In addition, structured comparative analysis may be used to organize and optimize case study analysis to provide analogical and metaphorical inspirations for design.

Despite its significance, the structured comparative analysis of the built form did not receive sufficient attention in recent architectural literature. Examples of related literature include a critical study of modern architecture (Frampton and Simone, 2015), a provocative reading of Palladio's plans (Eisenman and Roman, 2015), a collective procedural study of Palladio villa designs (Eilouti, 2008), and a comparative analysis of the design schemes of Palladio and Sinan buildings (Eilouti, 2012). Related studies in the area of PBD have also been conducted. An example is the study of Eilouti (2009) that focused on design approaches using knowledge recycling from precedent-based analysis and synthesis models. Although these few examples contribute to the architectural design literature, the area of scholarly comparative critical analysis of architectural designs is still under-researched.

This study is based on the premise that architectural compositions convey a formal language that has a structure similar to that of natural languages. As such, architectural composition has a set of vocabulary elements (with semantics and semiotics) and syntax grammars (e.g., Natapov et al., 2016). The analogy between visual and verbal languages is well established (e.g., Summerson, 1966). The generation of complex structures using a set of primitive elements and a precisely formulated set of grammar rules is based on Noam Chomsky's generative grammars (Chomsky, 1956, 1965; Gandelzonas, 1983). Influenced by Chomsky, Peter Eisenman designed a series of residential designs, which he called "cardboard architecture." In these designs, Eisenman embodied what he referred to as "deep structure," through which he attempted to explore the concept of "visual syntax." The complex nature of this approach stemmed from Eisenman's interest in language structure and semiotics, which he obtained through his study of Chomsky's works. In Eisenman's architecture, the design process is synchronized with the research process into formal structures and fractal geometric shapes (Eisenman, 1983; Gandelzonas, 1983).

Following the same language-based approach, Eisenman and Roman (2015) graphically analyzed 20 of Palladio's villas and illustrated the evolution of Palladio's villas from those that exhibit earlier classical symmetrical volumetric structures.

The present research focuses on the analysis of the morphology, geometry, and mathematics of some architectural designs of two influential architects that lived in nearly the same historical period (approximately 500 years ago) but in two different locations and representing two different cultures (that is, Western and Islamic cultures). The two prominent architects are Andrea Palladio who represents Western architecture and Sinan who represents Islamic architecture in the Renaissance period. Andrea Palladio is an Italian architect who lived from 1508 to 1580. He is widely considered one of the most influential architects in the history of Western architecture (Norwich, 1975). Sinan lived nearly in the same period (1489-1588). Similarly, he was considered as the chief Ottoman architect during his entire career and is universally classified as one of the most remarkable architects in the history of Islamic architecture. The study of key architectural precedents of the works of these two architects is expected to enhance the mapping and comparison of the design language structures and architectural composition principles of the two cultures during the same temporal framework.

A review on the literature backgrounds of the designs of Palladio and Sinan yields two observations. First, the architectural library is rich with research and publications on the works of Palladio and Sinan, each studied independently. Examples include the studies on Palladio's designs (Ackerman, 1967; Constant, 1993; Murray, 1971; Norwich, 1975) and the formal language of Palladio's palazzo façade language (Eilouti, 2008). Other examples include studies on Sinan's designs (e.g., Goodwin, 1993; Necipoglu, 2005; Özer, 1987; Rogers, 2006; Saoud, 2007).

The second observation is related to the suggestion of some architectural studies that indicated mutual influences between Islamic and Western architectures in the Renaissance period on the basis of the frequent exchange in trade and travel (Howard, 2000). For instance, a few comparisons between Sinan and several Italian Renaissance architects and artists, such as Michelangelo and Alberti, have been made (Vasari, 1963). Several examples of these comparisons proposed the mutual influence of design principles between Italian and Ottoman architectures during the Renaissance period (De Osa, 1982; Howard, 2003; Kostof, 1995). These instances proposed the existence of several similarities between Western and Islamic architectural precedents based on visual analyses.

Despite existing efforts, the area of structured comparative analysis that examines the commonalities and differences between Sinan's and Palladio's designs still needs exploration. This research is designed to contribute to knowledge in this particular area. This research addresses the comparative morphological study of a sample of the designs of the two architects. Notably, the main concern of this research is the visual study of the precedents rather than the cultural or social factors that may have affected their designs. The visual study focuses on the exploration of the commonalities and differences in the morphological and

compositional languages of key examples that represent them.

In this research, morphology is expressed mainly by the mathematical proportions, topological relationships, and compositional principles that underlie the selected architectural designs.

Within the scope of this research, case studies will be mainly represented by the ground floor plans of two architectural masterpieces selected from the designs of Sinan and Palladio. The selection is based on six criteria, where both cases are (1) classified as religious or sacred buildings; (2) characterized by having grand scales where both host mass prayers, that is, one is represented by an imperial mosque and the other is a ceremonial basilica; (3) widely considered major pinnacles in the careers of their designers; (4) erected on challenging sites; (5) constructed during relatively the same historical period; and (6) represent the architectonic and formal discourse of their architects.

The consistency in typology, scale, significance, language, location, and temporal backgrounds create a more objective method to compare the two designs.

2. Research methodology

This study is based on the visual analysis of morphology and the basic mathematical comparisons of architectural designs. The overall structure of the analysis is illustrated in the flowchart shown in Figure 1.

As illustrated in Figure 1, the formal language of architectural compositions may be classified into three categories, that is, morphological, semantic, and pragmatic levels.

2.1. Morphological aspects

Within the morphological level, the analysis will be conducted on the (1) morpholexical, (2) morphosyntactic, (3) morphometric, and (4) morphographic levels.

The first level is mainly concerned with the lexicons that deal with the small entities, words, or lexemes of formal language. In this research, these lexicons are the main geometric building blocks of the architectural precedent design. These lexicons are classified into planimetric, that is, two-dimensional shapes, such as squares and circles, and

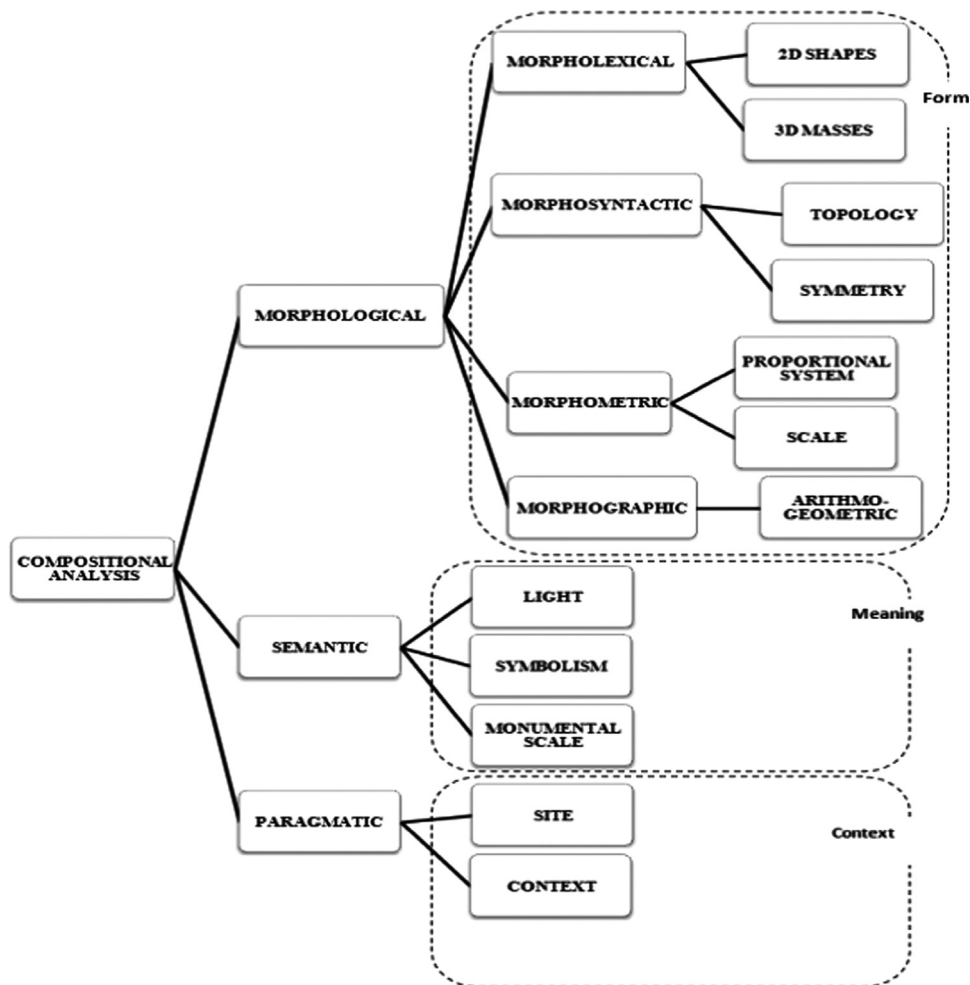


Figure 1 Organizational structure of the morphological analysis process.

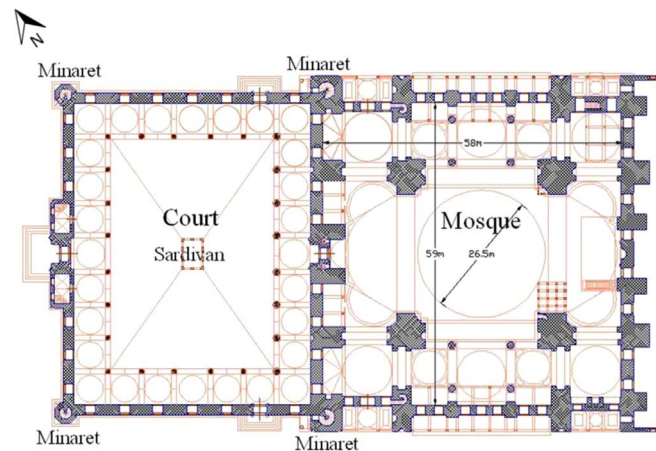


Figure 2 Floor plan of the Süleymaniye mosque (Redrawn by the author based on images from Arapi (2005a) at https://archnet.org/media_contents/49297).

volumetric, that is, three-dimensional masses, such as cubes, cylinders, and cones.

The second level is mainly concerned with determining how the basic entities are clustered together and identifying the grammar rules that control the clustering of the lexemes into meaningful structures.

The third level is mainly concerned with the relative numeric ratios of the dimensions of the design elements.

The fourth level is mainly concerned with the arithmo-geometric representation of the proportional system that regulates each case design.

2.2. Semantic interpretation

The semantic level focuses on the meanings that may be concluded from the spatial structures and the manner in which they are organized internally and externally. This level includes the meanings conveyed, the connotations concluded from the spatial organizations and internal environments of the buildings, and the employment of lights and symbols to enhance the appearance of and experience in the buildings.

2.3. Pragmatic forces

The pragmatic level focuses on the pragmatic factors where site and context are considered. This level highlights how the building designs have responded to their direct environments.

This study includes two parts. In the first part, each case is analyzed using the levels illustrated in Figure 1. In the second part, the individual analysis of each case is followed by the comparison of the conclusions derived from a set of commonalities and differences of the two design languages.

3. The case studies

Within the scope of this research, the case studies will be represented by the main floor plans of two buildings, that is, the Süleymaniye mosque by Sinan and the *Il Redentore*

church by Palladio. These buildings were selected based on the criteria explained in the “Introduction” section.

3.1. Süleymaniye mosque

The first case is a mosque (*Jamii'* in Arabic or *Cami/Camii* in Turkish), that is, an Ottoman imperial mosque that had been erected on a challenging terrain of a steep hillside located in Istanbul, Turkey. The architectural style of the mosque is Ottoman classical. The mosque was built during the sovereignty of Sultan Suleiman I (Suleiman the Magnificent) and named after him. The mosque was designed by the Ottoman architect *Mimar Sinan* (*Mimar* means architect in Arabic and Turkish) and constructed in the period of 1550-1557 (Necipoglu, 1985, 92). Süleymaniye mosque is part of a multipurpose complex, which demonstrated Sinan's competence as an urban designer and established his reputation as the foremost Ottoman architect and engineer.

The shape of the Süleymaniye mosque floor plan is basically a domed square in its major praying hall (Figure 2). As illustrated in Figure 2, the central square is elongated and flanked by two semidomed rectangles. The semidomes are connected from both sides by large arches and encompass tympana filled with windows (Figure 3). This central domed space is preceded by a monumental rectangular *Sahn* (Arabic for courtyard). The central *Sahn* is of exceptional grandeur and is surrounded by a colonnaded peristyle (or tetrastoon) that consists of grand columns enclosing repeated cells of domed spaces. The external four corners of the courtyard have four minarets for the declaration of prayer time (or *Athan* in Arabic). The four minarets are added to signify the four caliphs of early Islam. The minarets have a total of 10 galleries (2 for each of the front minarets and 3 for each of the back minarets), which indicate that Suleiman I was the 10th Ottoman Sultan (Necipoglu, 1985, 106). In addition to its main entrance that is aligned with the middle of the main façade of the courtyard, the mosque has six other lateral entrances (three located on the northeastern side and three on the southwestern side).

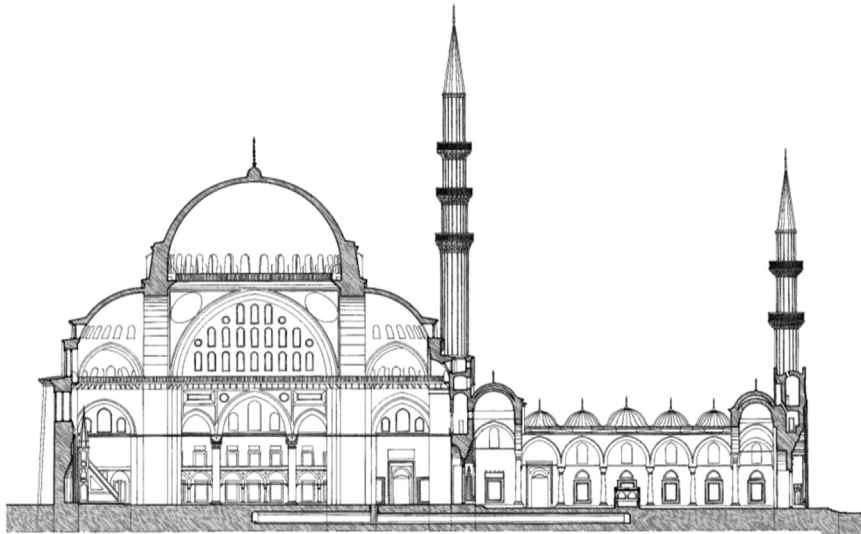


Figure 3 Section of the Süleymaniye Camii.

Source: <http://www.designcoding.net/suleymaniye>, Accessed 20 March 2017.

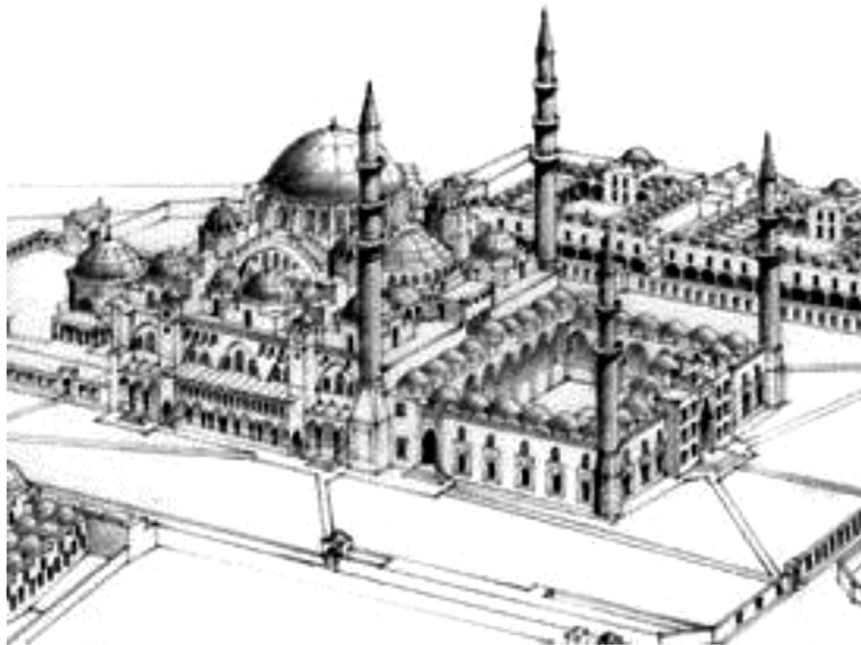


Figure 4 3D image of the Süleymaniye Camii.

Source: Arapi (2005b) at <http://www.archnet.org> (https://archnet.org/media_contents/42979).

All spaces are naturally well lit and open to each other. The spatial organization, vision line, and natural light flow smoothly from the central area under the dome through the broad arches to the aisles on all sides (Figures 3 and 4).

The *Sahn* is accessible through the main entrance that is preceded by a wide stair. Characteristically, Sinan emphasized the *Sahn* by raising it on an artificial platform. He further emphasized the *Sahn* space by locating a *Sadirvan* (ablution fountain in Turkish) at its center.

Structurally speaking, given the available materials during the construction period, Sinan could establish a large span under the dome. He could also skillfully mask the large side buttresses that were needed to support the four central

piers of the inner praying hall. He incorporated the buttresses into the walls of the building, with half of them projecting inside and half of them projecting outside to make them look less massive. Furthermore, he had intentionally hidden the external projections by building colonnaded galleries around them (Eilouti, 2012).

3.2. Il Redentore church

The second case is the famous Venetian Chiesa del Santissimo Redentore (Church of the Most Holy Redeemer). The church was designed by Andrea Palladio and constructed in

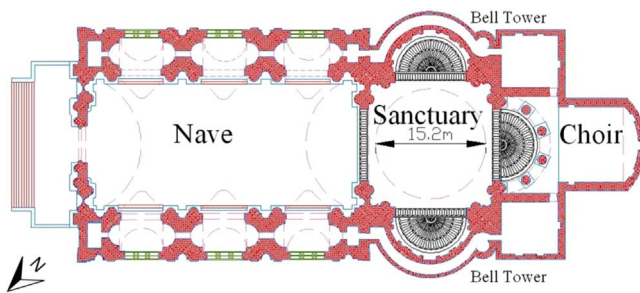


Figure 5 Floor plan of Redentore church (Edited by the author based on images from Blaser and Stucky (1983) at http://www.greatbuildings.com/buildings/Redentore_Church.html, Accessed 10 January 2017).

the period of 1577-1592 on the island of Chiesa del Redentore in Venice, Italy. The architectural style of the church is Renaissance.

The church consists basically of three major parts (Figure 5). As illustrated in Figure 5, the first part is the nave, which is rectangular in shape and has three divisions on each side of the main structure of the *Basilica*. Each division has side chapels that are connected to each other. The second part is the *Sanctuary*, which is a domed crossing that is centralized and squared in its focal part. The *Sanctuary* central space is domed and flanked by two semidomed semicircular apses on either side and ends with a hemicycle of columns that surround the altar. Two bell towers are placed on the sides of the cupola that separate this part from the third part. The third part is the cross-shaped choir. The smooth spatial organization of the three linked vaulted spaces allows vision, light, and sound to flow smoothly throughout the building. The light element is further emphasized by a set of clerestory windows (Figure 6). The decoration of the church is simple, and its main ornamentation comes from the architectural details of the columns, continuous entablatures, framed arches, and railings. The main order of the columns is Corinthian. All spaces are externally and internally individually articulated yet integrated and unified.

The main facade is oriented toward the northeast and is designed to reflect the internal volumes of the nave and side chapels (Figure 7). The central building front facade is given prominence by its monumental scale and perfect symmetry and by being raised on a podium that is introduced by wide steps (Figure 7). Composite pilasters and half columns frame the large central door. Motifs of triangular pediments recur at each side of the main portal. In addition, half pediments are placed in front of the side chapels. All front pediments are integrated into a large central triangular pediment. The facade also includes tympana-crowned niches (Figure 7).

4. Morphology of the two precedents

This section focuses on the morphological analysis of the two precedents. Each analysis focuses on the vocabulary elements or “words” of the architectural language that the case “speaks.” The analysis also explores the principles used to structure the “sentences” and the meanings and symbols it implies. Within the compositional principles, the

proportional system is particularly emphasized. In this sense, the morphological analysis applied to each precedent consists of four levels, that is, (1) morpholexical, (2) morphosyntactic, (3) morphometric, and (4) morphographic or arithmo-geometric analyses.

4.1. Morphology of the Süleymaniye plan

The plan articulation indicates that the spatial planning technique underlying its structure is based on a clear manipulation of a rectilinear grid. The overall regulating grid unit is the domed cubical cell comprising the layer behind the colonnade that surrounds the main *Sahn*.

4.1.1. Morpholexical analysis

In terms of the plan language, the main lexemes or building blocks are square, circle, and semicircle. Regular octagons are also part of the lexical group and can be mainly observed in the minaret projections. The lexical components are repeated with various scales. The three-dimensional blocks include the parallelepiped, cube, cylinder, cone, and hemisphere (Figure 4).

4.1.2. Morphosyntactic analysis

In terms of the syntax, the formal lexemes were subject to multiple transformation operations. These operations include scaling, stretching, mirroring, transmission, and rotation. These operations are also augmented by the subtraction of several elements, such as the semicircles, and the addition of other elements, such as the cubical cells.

The adjacency of blocks is the main topological relationship. No intersections or overlaps exist between plan units.

The main clustering and enclosure techniques are centralization of masses around a focal space using perfect symmetry. The central space is either positive (prayer hall) or negative (*Sahn*). Both modeling techniques of addition and subtraction of masses are applied. The addition technique can be observed in the buttresses, and the subtraction technique can be observed in the *Sahn* space.

4.1.3. Morphometric analysis

Each unit of the regulatory grid is assigned a proportion of $1X \times 1X$ (see Figure 8). All other measurements are relative to this unit and considered its multiples. The major spines of this plan are associated with the main structural axes and planning outlines. As illustrated in Figure 8, the main proportional ratios used in relating the elements of this plan are 1:1; 5:7, and 7:9.2. The major proportion of the courtyard is 5:7, which is equivalent to 1:1.4 (an approximate ratio of a side of a square to its hypotenuse = $1: \sqrt{2}$). Other major proportions of the courtyard include 1:1 in the repeated cells and 7:9 in the outer circumference. The width of the central “positive” space in the mosque equals that of the “negative” *Sahn* (denoted as $5X$). However, their lengths differ ($5X$ in the central “positive” space and $7X$ in the “negative” *Sahn*). The middle dome compartments to the northeast and southwest of the main praying hall are $1.8X$ in width, whereas the corner compartment to the left is $2.2X$ in width.

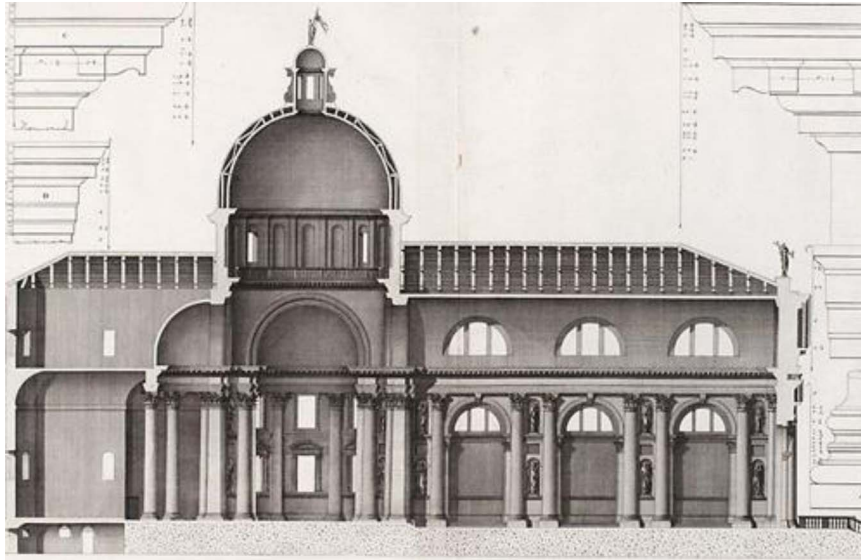


Figure 6 Section of the Redentore church.

Source: Drawing by Ottavio Bertotti Scamozzi, 1783; https://commons.wikimedia.org/wiki/Category:Le_fabbriche_e_i_disegni_di_Andrea_Palladio#/media/File:Chiesa_Redentore_sezione_1_Bertotti_Scamozzi.jpg (1783), Accessed 20 March 2017.



Figure 7 Front elevation of Il Redentore Church.

Source: http://www.greatbuildings.com/cgi-bin/gbc-drawing.cgi/Redentore_Church.html/Redentore_Elevation_2.jpg

In addition to this overall regulatory system, another subsystem can be introduced for the lower right part of the floor plan of the mosque. This part is illustrated in Figure 9. In this part, Sinan used subtle geometric relationships based on multiples and divisions of the grid unit X . The proportional subsystem used in this part is based on a 0.25 subunit square, which is used to set the width of the smallest compartment of the exterior gallery. The square in this plan is applied recursively, where one square calls and defines other similar yet smaller squares within each other. This layout insinuates, in a simplified version, an early application of fractal geometry in architectural design.

4.1.4. Morphographic analysis

The proportional system applied to this plan is illustrated by an arithmo-geometric representation that uses basic regular equilateral convex polygons to illustrate the main proportions recurred in the plan (Figure 10). For this plan, the set of polygons consists of regular tetragon, regular hexagon, and regular heptagon. The basic unit in this representation is a square with one unit measurement for each side. The ratio of its side to its hypotenuse is 1:1.4 or 5:7. As illustrated in the floor plan, this ratio is used in relating the width of the courtyard to its length. With a heptagon constructed on one of the edges of the basic square, the lengths of two of its diagonals illustrate two other ratios used in the plan, that is, 1.8 and 2.2. The first ratio is used when the basic grid unit is multiplied to assign the middle dome space on either side of the central dome. The second ratio is used in the multiplication of the basic unit to yield the width of the domed spaces located at the right of the middle minarets. The diagonal length with the second ratio is used to construct another heptagon. The five-unit diagonal represents the width of the courtyard. The measurement of the shortest chord of this heptagon is used to construct a hexagon. The length of the chord, that is, $7X$, represents the courtyard length, and the total of the length of the chord and the side of the proceeding heptagon, which is $9.2X$, represents the ratio of the width of the southwestern façade of the building (see Figure 8).

The 0.25 subunit of the regulatory grid explained in Section 4.1.3 (Figure 9), along with its multiplications, can be represented by a Pythagoras tree, which illustrates recursively repeated geometric forms (fractals) that are applied, in this case, with symmetric 45° right-angled triangles and squares constructed on their sides (see Figure 11).

4.1.5. Semantic analysis

This aspect is not considered directly morphological, but is associated with the formalistic layer of the compositional

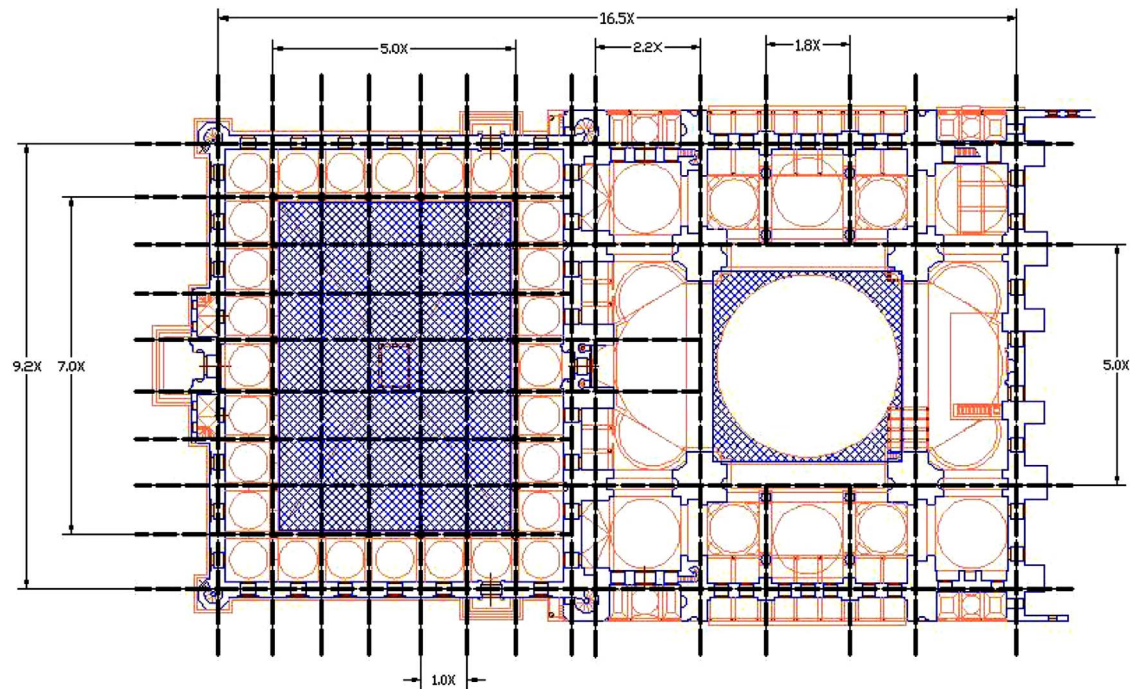


Figure 8 The regulatory planning and proportional systems of the mosque.

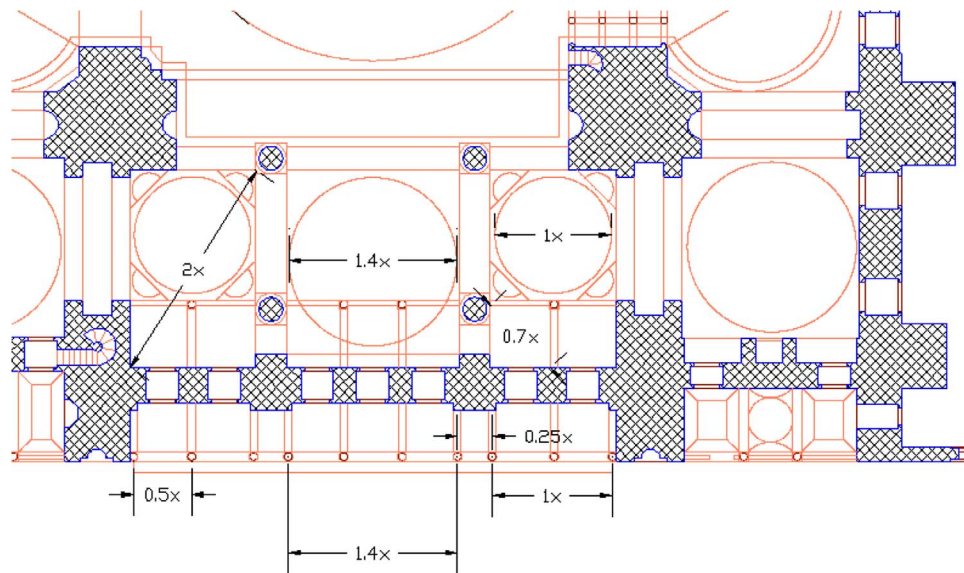


Figure 9 Magnified view of the lower right corner of Figure 8.

language. Such an association helps add a layer of interpretation of several compositional rules. The main semantic attributes include the following:

- The progressive rhythmic accumulation of masses from the front facade ascending to the climax in the praying hall, implying a transcending effect from earth to heaven while accessing the prayer hall (Figures 3 and 4).
- The flow of vision and light emphasizes the unity of the universe (Figure 3).
- The overwhelming natural light emphasizes the divine light that accentuates the spirituality and the connection of the inner spaces to the cosmos.
- The monumental scale conveys a feeling of grandeur and prestige.
- The prominent hilly site adds to the semantic value of the mosque.
- The centrality of the mosque within the urban complex signifies its focal role in the community.

4.1.6. Pragmatic analysis

The building continues visually on its hilly site in pyramidal composition and works in harmony with its site. The water element is introduced inside its courtyard as a functional component that serves for ablution and is articulated as a

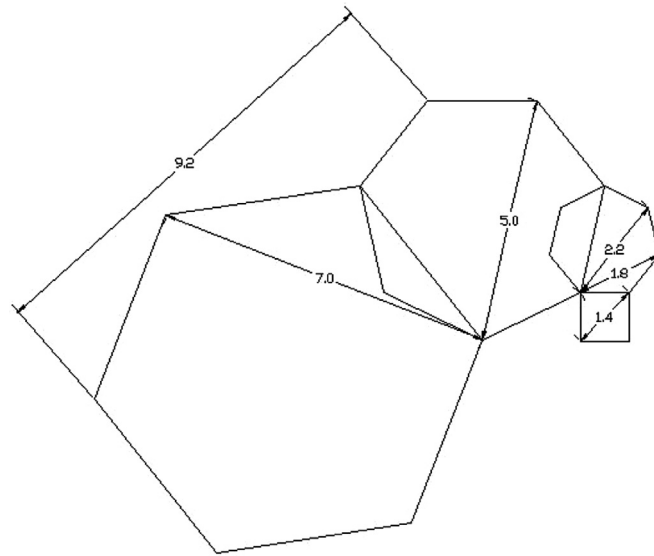


Figure 10 Arithmo-geometric representation of the Süleymaniye proportions.

fountain that is located at the center of the *Sahn* space. The building also complements its urban surroundings in a multipurpose complex where different functions complement each other.

4.2. Morphology of II Redentore church plan

Similar to the study of the first precedent, this analysis consists of four levels, that is, (1) morpholexical, (2) morphosyntactic, (3) morphometric, and (4) morphographic or arithmo-geometric analyses. These four levels are also supported by two extra levels, that is, the semantic and pragmatic levels, to add another layer of language interpretation.

4.2.1. Morpholexical analysis

In terms of the compositional language of the floor plan, the lexical structure consists of rectangles, squares, and circles, in addition to their divisions, that is, semicircles and triangles. In addition, the facades include triangles (pediments, see Figure 7). In 3D, the massing includes parallelepiped, cones, cylinders, hemispheres, and pyramids.

4.2.2. Morphosyntactic analysis

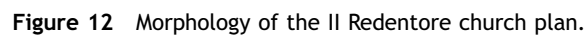
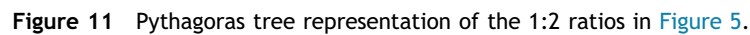
In terms of the syntax, similar to that in the floor plan of the first case, the adjacency of blocks is the main topological relationship. Similar to their correspondents in the mosque floor plans, the lexemes of this design language were subject to multiple transformation operations, such as scaling, stretching, mirroring, transmission, and rotation. The main clustering technique is linear. The addition of masses is dominant, with few minor examples of subtraction. An example of the first operation can be observed in the pitched roofs and buttresses. An example of the second operation can be observed in the cylindrical niche components. The hierarchy of the sizes of different components is clear in the sequence and subdivision of spaces. The sequence of spaces moves from larger spaces in the front and middle to smaller spaces in the back and sides.

4.2.3. Morphometric analysis

The basic planning regulatory unit for the II Redentore church floor plan is the width defined by the distance between the main axes that underlie the repeated module of the side chapels (Figure 12). This module is used to divide the main nave into three parts on either side of the axis of symmetry that passes through the horizontal middle point of the floor plan and is assigned a proportion of $1X$ (X here is different in dimension from that of the first case). This length is repeated in the nave area four times. Another repetitive proportion in this part is the golden section ratio $1:1.6$ (or $5:8$). The basic grid creates a series of golden rectangles (proportioned $1:1.6$). Another ratio applied in the nave part is $1:1.4$ (a side of a square related to its hypotenuse). The length of the nave is $7X$. In terms of the X unit, the width of this space is twice the golden section $3.2X$ ($2 \times 1.6X$). The same proportion is used in the sanctuary area ($1:3.2$). This area is centered about a square of $3.2X$ sides. Similarly, the golden section ratio is used as the width of the monastic choir space ($1.6X$). Along with this ratio, half of the basic length, that is, $0.5X$, and $2.2X$ are used in this space (Figure 12). The spatial planning and structural axes are also laid out using the ratio of $1.2X$ ($1:1.2$ or $5:6$) on both sides of the symmetry axis. The sides next to the choir space exhibit the ratio of $3:4$.

4.2.4. Morphographic analysis

Parallel to the analysis of the mosque floor plan explained in Section 4.1.4, the proportional system of the II Redentore church floor plan is explained by an arithmo-geometric representation that uses basic regular polygons (Figure 13). In this plan, the set of polygons consists of a square, a regular pentagon, and a regular hexagon. The basic unit in this representation is a square with one unit measurement. The ratio of its side to its hypotenuse is $1:1.4$ or $5:7$. As shown in the plan (Figure 12), this ratio is used in relating the width of the span between the two axes of the transitional area between the nave and the sanctuary to the width of the side chapel. The basic square is repeated to represent the 2.2 ratio that is used to represent the width



- The progressive rhythmic accumulation of masses from the front facade ascending to the climax in the sanctuary hall, implying a transcending effect from earth to heaven when accessing the altar space.

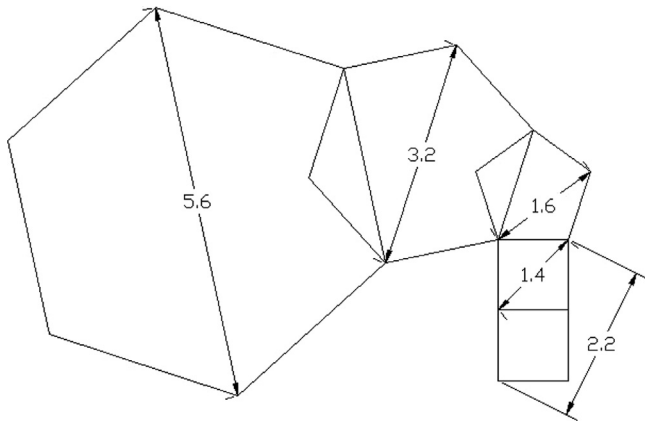


Figure 13 Arithmo-geometric representation of the Redentore church proportions.

- The flow of vision and light emphasizes the unity of the universe.
- The overwhelming natural light emphasizes the divine light that accentuates the spirituality and the connection to the cosmos of the inner spaces.
- The monumental scale conveys a feeling of grandeur.
- The front pediment center emphasizes the main longitudinal axis that points out the focal altar.

4.2.6. Pragmatic analysis

The building floats visually on its island location. The water element in the mosque was employed internally as a functional fountain. By contrast, the water element in the church was used externally to provide an impression of divine lightness and reflectivity. The church looks like a ship that floats on the surface to symbolize escape and survival.

5. Comparison and discussion

From the analyses of the case studies presented and the images illustrated in the previous sections, the two precedents exhibit a set of similarities and differences. These similarities and differences are discussed in the subsequent sections.

5.1. Morphological convergence

Notably, both cases exhibit multiple similarities on many levels, including the morphosyntactic, semantic, proportional, and arithmo-geometric representations.

From the analyses presented in the previous sections, both precedents evidently share the following:

5.1.1. Morpholexical aspects

- Apply cross-vaulted substructures.
- Share basic geometric shapes, such as circles, squares, and rectangles in plan and cubes, cones, cylinders, hemispheres, and semidomes in volumes.
- Share vertical monumental architectural elements, which are articulated as minarets in the mosque and bell towers in the church (geometrically, consisting of cylinders and cones in both cases).

- Use similar structural elements, such as main large piers, buttresses, domes, semidomes, and cross-vaults.

5.1.2. Morphosyntactic aspects

- Consist of symmetrical massing schemes.
- Are built on raised artificial platform/podium, each of which unifies the various volumes it consists of and enhances their monumental scale and identity.
- Are characterized externally by the rhythmic repetition of basic geometric forms. Their rhythms provide the appearance with harmony, integrity, and unity.
- Are sequentially connected internally with harmonious articulated yet integrated pure spaces.
- Designed with simple ornaments. The spatial organizations are relatively complex, which made extra ornamentation unnecessary.
- Illustrate a basic application of a rectilinear grid to organize the various space topological relationships.
- Consist of a centralized domed structure that is preceded by a rectangular part.
- Enhance the appearance with tympana-crowned framed windows and niches.
- Share the system of four central piers that collectively hold the central dome.

5.1.3. Morphometric aspects

- Share several common ratios, including the ratios of 1:1, 1:1.4, 1:2, and 1:2.2, in their governing proportional system.

5.1.4. Morphographic analysis

- Share in their arithmo-geometric representations several basic polygons, including a tetragon and a hexagon.
- Are represented by similar Pythagoras trees.

5.1.5. Semantic aspects

- Employ natural light to reinforce the spiritual implications of divinity in both sacred places.
- Employ geometry that embodies strong symbolism to convey messages to the users and viewers. As such, the two cases employ hemispheres to represent heaven and tall vertical elements to hint a connection between earth and sky.
- Exhibit attributes of the classical style, such as basic geometric shapes, symmetry, monumental scale, introductory stairs, and platform, to emphasize purity and grandeur.
- Employ monumental scale to highlight the prestige of the sacred identity of the buildings.
- Are characterized by continuous light-filled spaces that flow smoothly visually, acoustically, and spatially, emphasizing the impression of unity in the spaces and with the universe.

5.1.6. Pragmatic aspects

Both cases complement a challenging site with harmonious response to context.

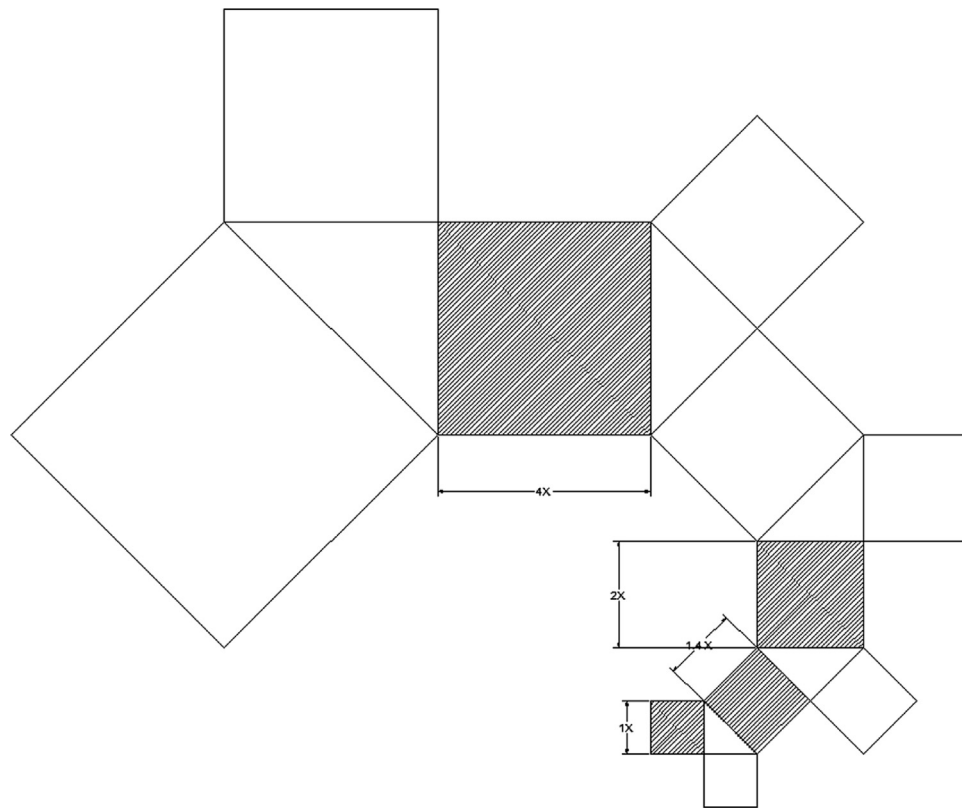


Figure 14 Branch in the Pythagoras tree representation of the proportions in Figure 12.

In addition to the commonalities listed previously, the nine-square regulatory scheme in its modified version of nine-rectangle grid underlies the structures of both layouts (Figure 15). In Sinan's plan, the scheme is applied twice, that is, one with the central praying (positive) space as its middle square and the other with an outdoor (negative) space. In Palladio's plan, the scheme is applied once with the left part of the grid elongated to enclose the main praying space and make it more spacious. The central space is a (positive) space that encloses the sanctuary. This point is further discussed in another research (Eilouti, 2012).

5.2. Morphological divergence

Despite the commonalities discussed in the previous section, Sinan's Süleymaniye and Palladio's Redentore differ in several design aspects, as follows:

5.2.1. Morpholexical aspects

- The design of Redentore employs triangles, such as in pediments, which are not apparent in the design of Süleymaniye. This aspect can be explained by the cultural differences, where pediments are more common in the Western architecture.
- The occurrence of cylinders and hemispheres is more frequent in the mosque than that in the church.

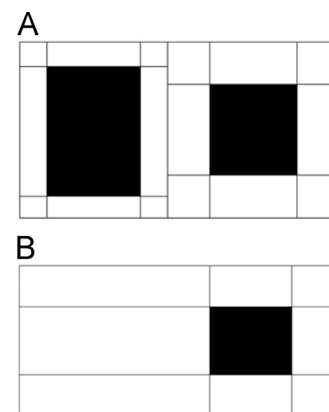


Figure 15 A nine-square grid abstraction of the two floor plans. (A: Süleymaniye, B: Redentore).

5.2.2. Morphosyntactic aspects

- Redentore is characterized by one major façade (the northeastern) and other minor façade. By contrast, the four external façades of Süleymaniye are emphasized almost equally.
- The rhythm of component repetition is different in both buildings and is characterized by more variety in the church.
- The adherence to the grid in the spatial planning of architectural components is stronger in the mosque than that in the church.

- The integration of several landscape elements (water in particular) differs in both buildings. The water element is incorporated internally in the mosque, as represented by the central fountain (*Şadırvan* in Turkish), but incorporated only externally in the main façade of the church in its adjacency relationship with the waterfront.
- The standardization and modularity of spaces and architectural components, although used in both cases, is more intensive in the mosque (for example, see the domed cells surrounding the courtyard in Figure 2).
- The church is mainly accessed by one entrance, whereas the mosque has, in addition to its main entrance, six other lateral entrances (two from the courtyard sides and four from the central mosque space sides).
- In terms of the structural design, larger spans and structures were accomplished in the mosque than in the church.

5.2.3. Morphometric aspects

- The ratio of 1:1.6 (the golden section) is more dominant in the church, whereas the ratio of 1:1 is more frequent in the mosque.

The scale of the mosque is larger than that of the church. For example, the diameter of the dome of the mosque is longer than that of the church.

5.2.4. Morphographic representations

- In the arithmo-geometric representations, heptagons are used in Süleymaniye, whereas pentagons are used in Redentore.
- The application of fractal geometry, as illustrated in the Pythagoras tree representation, is clearer in the mosque than that in the church.

5.2.5. Semantic aspects

- When dealing with the external architectural planes, Sinan seems to be more interested in simplification than in enrichment perhaps because of the complexity of massing. The main difference in Palladio's design lies in the articulated treatment of the main façade.
- The orientation of the mosque is cosmopolitan and points its focal point (*Mihrab*) to the *Qibla* direction in Mecca for religious reasons. The orientation of the church is localized and is affected by the major forces of the local site and context.
- The total number of minarets and galleries around them are employed to semantically convey messages about the Sultan's power and order in the mosque. By contrast, the geometry of Redentore does not reflect a personal reference.

5.2.6. Pragmatic considerations

The church uses the water element externally to enhance its appearance and context, whereas the mosque employs the water element internally as an ablution fountain. In addition, the mosque complements its surrounding buildings

in a coherent urban complex, whereas the church is individual and independent.

In summary, from the comparison of the two designs, establishing a correspondence between the two languages in terms of their vocabulary, grammar, and symbolism becomes possible. In this sense:

1. Lexically, the two architects used almost the same building blocks. On the two-dimensional level, the two architects used squares, rectangles, circles, semicircles, and arches. On the three-dimensional level, the vocabulary elements of the two architects include masses, such as hemispheres, cylinders, cones, cuboids, and parallelepipeds. However, Palladio used triangles and pitched roofs more frequently, whereas Sinan did sparingly. Similarly, Sinan used negative or subtracted spaces represented in the courtyard element, whereas Palladio did not.
2. Syntactically, the two architects employed a structure-related regulatory grid to organize their spaces and structural elements. The sequence of spaces represents a combination of individual spaces, each of which is self-sufficient and an open continuation to its surrounding spaces. Each space flows smoothly in terms of the natural light, vision, acoustics, and topology in both cases. In addition, hierarchy, repetition, harmony, and variety are used in both plans to control their compositions. The proportional systems in both cases share the employment of the ratios 1:1, 1:1.4, 1:2, and 1:2.2. Moreover, both cases exhibit a successful combination of simplicity and complexity in plan articulation and massing treatment. Coincidentally, the nine-square grid in its modified version of nine-rectangle grid seems to underlie the planning schemes of both plans.
3. Semantically, the centrality and symmetry of the spaces helped emphasize the significance of the main prayer spaces. The perfect symmetry and rhythm of both cases also symbolize balance in the universe. The employment of the dome in its symbolism to the universe or God's unity (Goodwin, 2003, 35), along with the utilization of natural light as it connects the various spaces, helped highlight the spirituality of the sacred spaces. The significance of the two buildings was further enhanced by the monumental podium that unifies the volumes of each building.

The commonalities between the two cases may be explained by two observations. The first point is related to the exchange of trade and tourism between Venice and Istanbul (Howard, 2000). Howard (2000) proposed that Venice's merchants imported more than material goods from the East, they also acquired a wealth of visual ideas and information from the Muslim culture. In her book, Howard (2000) argued that many Venetians gained insight into the Islamic culture through personal contacts with their Muslim trading partners.

The second point is related to the shared Byzantine culture that existed in both geographic locations and contributed to creating a shared foundation for their designs.

Table 1 Comparison between the compositions of the two precedents.

<i>Level</i>		<i>Süleymaniye</i>	<i>Il Redentore</i>
<i>Morphological</i>	2D Planimetric	<i>Square, rectangle, circle, semicircle, and octagon</i>	<i>Rectangle, square, circle, semicircle, and triangle</i>
	3D Volumetric	<i>Cone, cylinder, parallelepiped, octahedra, and hemisphere</i>	<i>Pediment, cone, cylinder, parallelepiped, pyramid, and hemisphere</i>
<i>Morphosyntactic</i>	Transformation operations	<i>Scaling, stretching, mirroring, transmission, and rotation</i>	
	Fractal geometry	<i>Exhibit an instance of fractal geometry</i>	<i>No fractal geometry</i>
	Modeling technique	<i>Both modeling techniques of addition (buttresses) and subtraction (Sahn)</i>	<i>Addition of masses is mainly dominant (the pitched roofs and buttresses), with few minor examples of subtraction (the cylindrical niche)</i>
	Style	<i>Classical style</i>	
	Topology	<i>The adjacency of blocks is the main topological relationship</i> <i>No intersection or overlap exists between plan units</i>	
	Clustering and enclosure	<i>Centralization of masses around a focal space, which is either positive or negative</i>	<i>The main clustering technique is linear</i> <i>No negative spaces</i>
	Layout scheme	<i>Symmetrical massing schemes.</i> <i>Balance between negative and</i>	<i>Symmetrical massing schemes.</i> <i>The sequence of spaces transitions from larger spaces in the front and middle to</i>

Table 1. (continued)

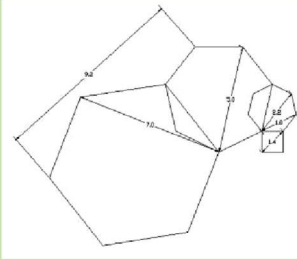
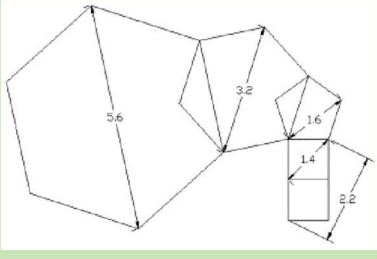
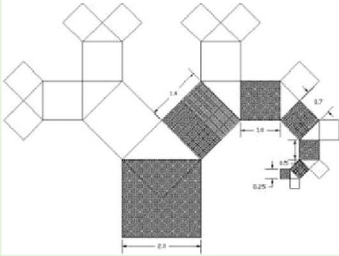
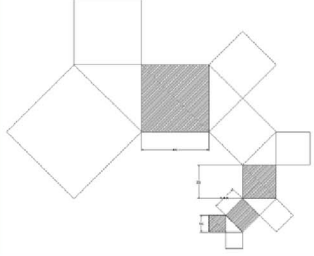
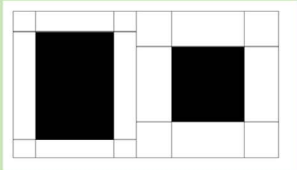
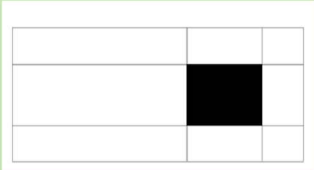
		positive spaces. Central flow of spaces Both extroverted and introverted spaces	smaller spaces in the back and sides. Introverted spaces
Morphometric	The recurrent proportions	1:1, 1:1.8, 1:√2, 1.8:2.2, 1:2.2, 5:7, 7:9.2	1:1.6 (or 5:8), 1:√2, 1:1.2 (or 5:6), 1:3.2, 3:4
Morphographic representation	Arithmo-geometric representation		
	Pythagoras tree representation		
	Nine-square representation		
Semantic implications	Light	Dominant natural light flow to emphasize spirituality	
	Scale	Monumental scale to emphasize grandeur	
	Symmetry	Perfect symmetry to emphasize significance	

Table 1. (continued)

	Symbolism	Symbolism of dome Centrality of prayer space Number of minarets and galleries Represents the Sultan's power	Symbolism of dome Centrality of prayer space
	Ornamentation	Less façade ornamentation	More façade ornamentation
Pragmatic fittings	Landscape site	Water element: internal	Water element: external
		Harmony with steep site	Harmony with island site
		Part of urban complex	Independent
		Oriented to Qibla	Oriented by site forces

The comparative analysis of the two precedents is further summarized in Table 1.

6. Conclusion

The structures underlying two architectural floor plans, that is, one representing a design by Sinan and the other representing a design by Palladio, are analyzed and compared on multiple morphological levels. The floor plans of Süleymaniye and Il Redentore are analyzed and compared on the morpholexical, morphosyntactic, morphometric, morphographic, arithmo-geometric, semantic, and pragmatic levels.

The result of the comparative morphological analysis showed that both architects meet significantly on the lexical and semantic levels of their design languages. However, the two architects differ in several aspects of the syntactic level of their languages. Similarly, both plans meet mathematically in several proportional system ratios, such as 1:1 and 1:1.4, but differ in other ratios, such the golden section ratio 1:1.6, which was applied intensively in Palladio's design, but missing in Sinan's design.

From the multiple commonalities of the precedents analyzed in this research, the distance between the two architectural languages is concluded to be closer than that implied by the initial external appearance. The geometric attributes of the classical style of the designs are similar, although the buildings vary in their geographic and cultural contexts. The similarities of both languages may be explained by the mutual exchange of trade and travel between Venice and Istanbul (Howard, 2000), which may have contributed to the transfer of visual images, and by using a similar regulatory planning grid and the nine-square grid as elaborated in the morphosyntactic analysis of this study. The semantic layer was also employed similarly in both cases. Both architects incorporated natural light to symbolize divine power, perfect symmetry to symbolize balance of the universe, vertical towers to imply a connection between earth and sky, monumental scale to signify

grandeur, raised podium to connote prestige, continuity of spaces to convey unity, and domes to symbolize heaven. The differences in the formal languages are either due to function or culture. An example of function is the ablution fountain in the mosque, which is not needed in the church. An example of culture is the pediment, which is more common in the Western architecture than that in the Eastern architecture.

Future extensions of this research include the comparative analyses of the three-dimensional articulations of the two precedents, the examination of other cases from the works of the two designers, and the exercise of imaginative simulations of the exchange of the vocabulary and grammar rules that underlie the planning, designing, and modeling techniques of the two designers to propose how a building may look if it was hypothetically designed by the other designer. Another extension may further emphasize the semantic, cultural, and social layers and analyze their effects on the designs in more detail.

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