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Fundamental Developments of 16th Century Ottoman Architecture: Innovations in the Art of Architect Sinan

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Abstract

This study aims to reveal and explain the principal innovations in Sinan's art. Although several previous studies have concentrated on Ottoman architecture and especially on Sinan's art, a distinctive research on the innovative contributions of Sinan had not been offered yet. By making use of the definitions of innovation given in the Oslo Manual, and searching the relevant literature, in which developments achieved by Sinan are claimed, an evaluation of innovative steps taken in 16th century Ottoman architecture by Sinan was articulated. The solutions introduced for the first time to structure, function and plan by Sinan were classified and given with the evidences of innovation. This classification was mainly based on the structural developments, together with their functional and aesthetic reflections, where other innovations of Sinan were also listed.

Key Words

Architect Sinan, 16th century, Ottoman architecture, innovation, structural developments.

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1. Introduction

Through the centuries, among different examples of architectural history, some works have proven to be outstanding ones for many reasons. Criteria for such an evaluation relate two perfections: one in structure and the other in aesthetic value. Moreover, an architect was also said to be an innovator as long as s/he contributed to building technology with structural or aesthetic aspects and as long as s/he influenced her/his successors.

If we look into architectural history, we may see several innovative contributors. But in on Ottoman architecture, there is undoubtedly one name of consensus: Sinan[1]. His genius in art and engineering resulted in architecture and he was responsible for the construction of approximately 400 buildings[2] while he was the chief architect of the Ottoman Empire for half a century (1538-1588). The aesthetic excellence of his works together with the variations and endless attempts for new forms made the architecture of his age "magnum opus" of the empire. His works crystallized the building tradition of the Ottomans. Moreover, the new ideas introduced by him to building technology gave birth to structural developments in Ottoman architecture and his followers adhered to these ideas for centuries, and this adherence continues even today.

But, can Sinan's contributions be counted as innovations or which of them can be regarded as innovative? The answers of these questions constitute the very aim of this study. The evidence of structural developments and/or their aesthetic and/or functional echoes have been offered so far in several papers and books, but a distinctive classification of innovations had not yet been offered. Hence, this study tries to list the structural and other developments which can be described as innovative.

An overall evaluation for the evidences of innovation in the art of Sinan will constitute the concluding remarks of this study. The level of these innovations, their future effects in Ottoman architecture and their place in architectural history will be the final statements, together with a critical analysis of Sinan's creativity.

2. The Approach of the Project

[1] Kuban writes: "Most probably the research on Sinan constitutes the half of the studies carried on Ottoman architecture. This attitude can be seen quite natural; because, the most important fruit of the Ottoman culture is architecture and Sinan is the most known and documented master of all." (Kuban, Doğan, *Osmanlı Mimarisi,* İstanbul: YEM Yayın, 2007, p. 17.)

[2] Aptullah Kuran, *Mimar Sinan*, İstanbul 1986, pp. 22-23.

This research followed three guidelines: Sinan bibliography given by Aptullah Kuran[3], design work and technology bibliography given by Selçuk Mülayim[4], and technology and mechanics history bibliography given by Yavuz Unat[5]. Relevant literature claiming innovations of Sinan was searched with the help of these bibliographies.

Hence, this study can be seen as a collection of data presented basically in several sources and their interpretation. But this collection follows a way of classification, and interprets them with respect to the international criteria of innovation. In fact, developments that were accomplished by Sinan cannot be classified as purely structural, functional or aesthetic. Because, to appreciate Sinan's architecture, one has to understand how structural form is connected to the aesthetic idea, and how each effort to strengthen the structure becomes a feature of the aesthetic form.[6] For the sake of obtaining a better understanding of those innovations, such a classification is made in this project.

The definition of innovation is argued and the meaning of this concept in architecture is discussed at the appendix in order to form a basis for the intended investigations. Therefore, the approach of this project can be described as linking these definitions with the observed developments, which were stated in the relevant literature, and discussing the presence of innovations in the work of Architect Sinan.

The improvements to be discussed are not given in full detail or they are not indicated for all the works of Sinan. Instead, general headings are used for the observable developments, and the innovative steps taken for accomplishing these developments is explained, together with the most important examples witnessed within Sinan's works related to that innovation.

Finally, as far as the field of this study is concerned, this essay can be regarded as an attempt within the discipline of "history of science and technology" mainly; but, it also aims to fulfill the requirements of architectural history.

3. Innovations Realized by Architect Sinan

For a complete understanding of Sinan's place and importance in architecture and his innovative contributions to it; one should firstly consider the historical context. Therefore, the evolution of architecture in the Islamic world, in Ottomans, and in the West will be given briefly to form a basis.

It can be said that Islamic architecture had completed a long evolution up to Ottomans since its beginning in the 7th century. The basic building was the mosque and the main intention was

[3] Kuran, 1986: 406-413.

[4] Selçuk Mülayim, *Ters Lale: Osmanlı Mimarisinde Sinan Çağı ve Süleymaniye,* İstanbul 2001, pp.304-308.

[5] Yavuz Unat, *Cumhuriyet Dönemi Türk Teknoloji ve Mekanik Tarihi Çalısmaları (1923-2004)*, Türkiye Araştırmaları Literatür Dergisi, Vol. 4, İstanbul 2004, pp. 103-133.

[6] Jale N. Erzen, *Sinan Ottoman Architect: An Aesthetic Analysis,* Ankara: METU, 2004, p.82.

gathering the believers under a unified space. The first important examples of mosques were Kufa and Basra Great Mosques and they were consisting of several columns bearing a flat covering. The most significant contribution of the eastern Islamic cultures in Persia to the development of mosque was the dome, which dates to the 11th century.[7]

Seljukid architecture represents a synthesis of previous developments in Anatolia as they continue the general scheme of the great mosque plan by borrowing an emphasized domed area before the mihrab. Silvan, Kızıltepe, Mardin and Erzurum Great Mosques constitute the early examples of them, which were constructed in the 12th century, while the later Seljukid mosques' interest on a central and large dome seem to predict the Ottoman emphasis for the central dome.[8]

If this evaluation is considered in the Ottoman context, Bursa and Edirne mosques become the developers of the previous period. For instance, the reversed T-model observed in the Bursa Green Mosque and the Mosque of Murat II could be considered as the steps before the first example of central domed mosque, namely Edirne Üç Şerefeli Mosque. This mosque clearly shows the emphasis on uninterrupted space and constitutes the prototype of sultanate mosques of Istanbul. However, Fatih and Bayezit mosques, the two important predecessors of Sinan's works, obtain their inspiration from Hagia Sophia (built between 532 and 537)[9] by means of using semi domes for enlarging the covered space.

The Western context and its evolution to the Renaissance should also be considered before dealing with the structural innovations introduced by Sinan. Justinian's Hagia Sophia becomes the most important creation of Roman architecture together with the Pantheon. These two examples not only influence Ottoman architecture and Sinan, but their fusion with the Islamic dome design create the works of Renaissance, such as Brunelleschi's Florence Cathedral.[10] However, the stress of such works was on the single dome and Sinan's efforts to deal with structure to transform a space into an uninterrupted one differs from Renaissance works. Moreover, they are all solitary examples amongst other diverse structural solutions of a period, and it is only for Sinan's architecture in its totality, which is a comprehensive system of the domed structure.[11] This is where Sinan diverges from his Western contemporaries.

It should be underlined that even the last important example before Sinan, namely İstanbul Bayezit mosque (Figure 1), was still carrying on a structural problem: the units of the structure were lacking unification. Mainstone explains the results of this problem as follows:

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[7] Ayla Ödekan, "Cami", in *Eczacıbaşı Sanat Ansiklopedisi*, İstanbul: YEM Yayın, 1997, p. 317

[8] Erzen, 2004: 9

[9] Rowland Mainstone, *Structure in Architecture: History, Design and Innovation*, Norfolk: Ashgate Publishing 1999, p. 209.

[10] Doğan Kuban, *İstanbul Yazıları*, İstanbul: YEM Yayın, 1998, p. 84.

[11] Erzen, 2004: 77.

> (…) All the elements remained sharply distinguished. The broad transverse arches that carry the central dome project well below the semidomes, for instance, isolating and emphasizing them, and isolating in turn the bays beyond them. And there is no continuity of cornice levels, lines of fenestration, or size of arch, to unify the whole.[12]

On the contrary, even the first sultanate mosque of Sinan, namely Şehzade, was representing the continuity of space and interdependence among parts. Therefore, it should be kept in mind that the solution that he brought to this problem distinguishes him from his predecessors. And this is the point where Sinan's works differ from previous Ottoman architectural examples and where one should look for his innovative contributions.

3.1. Structural Innovations Realized by Architect Sinan

Sinan had manipulated the structure in order to achieve the intended result and found different structural solutions for every single work. If one concentrates on the structure of his mosques, the source of those solutions arises from one key point: the double boundary system.

The realization of a building depends firstly on structure and as it becomes the most important feature of Sinan's concerns together with plan and form; his novel designs originate from a comprehensive structural solution. And if the evolution of Sinan's mosques is studied, the development of the double boundary system and its importance in structure would be clearly seen. Because the common approach of them are the same: second boundary envelopes the first and the structure widens in all directions:

> The quality of Sinan's work depends largely on the tightly knit structure. In Sinan's mosques the secondary structural and spatial parts are not just added to the core baldachin but are dependent on and supportive of it. This constitutes the basic structural principle of Sinan's mosques. In fact, as the plans indicate, the structural as well as the spatial solution depended on encircling the core with secondary spaces.[13]

In fact, Sinan skillfully places a real baldachin at the center, and the auxiliary structural elements, arches and buttresses surround it to form a secondary boundary. But when doing this, he pays a quite important attention to make these elements the only carriers of the mass; therefore he enables the transparency of the walls. As a result, he not only enlarges the space in an uninterrupted manner, but also increases the illumination of his buildings as the walls give up their weight carrying

[12] Rowland Mainstone, *Hagia Sophia: Architecture, Structure and Liturgy of Justinian's Great Church*, New York: Thames and Hudson, 1988, p. 251.
[13] Erzen, 2004: 78.

role and have the opportunity to contain extra windows. Therefore, it would not be wrong to regard this achievement, which was not present up to Sinan's time, as the most important innovation of him and the source of the developments that he introduced (Figure 1).

Accordingly, in this part of the study, the *observable results* of the structural improvements introduced by Sinan will be listed within six headings. In each heading, the innovations responsible for those developments will be argued, together with the examples from Sinan's works and quotations claiming those innovations. But it should be kept in mind that the above mentioned innovation of Sinan, namely the double boundary system, constitutes the core of all these structural improvements as well as the functional and aesthetic ones.

3.1.1. The Widening and Unification of the Main Space

As far as the motivation of mosque construction is considered, gathering the believers under a unified space becomes the first requirement. Hence, the development of structures for satisfying this aim can easily be interpreted as to be innovative. The first sultanate mosque of Sinan, namely Şehzade, fulfills this aim by introducing four semidomes on each side of the main dome. He reaches the ideal form both in interiors and exteriors as a result of the conceptual development beginning with Edirne Üç Şerefeli Mosque, and followed by Fatih and Bayezit Mosques[14] (Figure 2); because, for the first time in İstanbul the half-dome system of Hagia Sophia is exploited in a different kind of architectural style and an essential innovation in the spatial organization arises[15]. Besides, Mainstone points another innovative contribution of Şehzade as follows:

> Sinan's other innovation here – the replacement of the smaller domed bays to each side of the central dome by further large semidome bays identical with those on the main axis – was simply a further development of the structural system of the Bayezit Mosque. This gave a further expansion of the main central space laterally, and evaded the problems – both aesthetic and structural – of relating different systems on the two axes.[16]

On the other hand, if the widening of the main space is reconsidered, one observes that Sinan's masterpiece Selimiye gains the most important role in the gratification of this goal:

> The placement of an exterior buttress system, which will fulfill the dome effects, within a secondary space other than the central one; the enrollment of the support system elements in the solution of such a unification; the spatial

[14] Kuban, 1998: 103.

[15] Oktay Aslanapa, *Turkish Art and Architecture*, New York: Praeger Publishers, 1971, p. 218.

[16] Mainstone, 1988: 255.

> dominance of the main dome compared to the mentioned bearing structure can be read as a phase that Ottoman art of space has reached. Selimiye is the building which satisfies all these features and sums up the message of Ottoman style.[17]

After building several mosques, which are based on square or hexagonal plans, Sinan decided to build his masterpiece in Edirne on an octagonal scheme. In fact, he had made previous experiments for this baldachin structure in smaller scale and finally in Selimiye, he ended up with a diameter almost equal to Hagia Sophia. But Selimiye's importance of spatial unity depends on another structural innovation, which can be understood if the interior and exterior boundaries are investigated with respect to previous schemes:

> In each Sultan mosque of Sinan, Şehzade, Süleymaniye and Selimiye, in successive order, the baldachin is seen to be placed closer to the outer boundary. In Selimiye, the auxiliary spaces have been completely integrated to the whole. The great contrast between the completely unified space and the structural portions of the baldachin is largely responsible for the effect of spaciousness and gives measure to the enormous span. [18]

It is also possible to say that Sinan had designed his mosques by creating a transparent baldachin structure at first and situated the surrounding secondary parts so as to supply a wide and integrated interior space. Therefore the outer boundaries circles around the interior one just like the water circles caused by a drop, the opposition of these layers contribute to the spatial quality, and the result of these structural developments give an innovative result: widening of the interior space.

Another cause of this width can also be observed if one enters above mentioned three mosques from the central gateway. At first two, there is a delay for reaching the main space due to semidomes and the four piers limits the angle of vision. However, in Selimiye, one enters directly into the main space and feels the span of the huge dome. The field of vision widens from 66 degrees to 90 degrees due to eight piers instead of four[19] (Figure 3). And this can also be counted as another innovative evidence causing the same structural development.

3.1.2. The Increase in Luminosity

Another property of Sinan's mosques is known as the lighting of the interior space, which derives from the structural developments. By solving the structure of his buildings with logical steps,

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[17] Kuban, 2007: 460.

[18] Erzen, 2004: 82.

[19] Hans G. Egli, *Sinan: An Interpretation*, İstanbul: Ege Yayınları, 1997, p. 176.

he had the chance of inserting extra daylight into them; even he manipulated with it very well. In other words, distributing the covering system onto columns and piers, an important portion of which is moved to the exterior parts, not only supplied the unification of the space but also increased the lighting.[20] In fact, Sinan's vision included light because it was a sine qua non for viewing the operation of his domed interiors.[21]

Especially Edirnekapı Mihrimah Sultan Mosque takes a superior place in his works due to this effect. The semi domes, which play the role of buttressing in his other works, are removed in this special work of Sinan, and the side walls had the opportunity of having extra windows, which will yield to an augmentation of light for the interiors. The weight of the dome is carried only by four piers, which were highlighted with corner turrets and hidden skillfully inside the side walls, and four arches. This mosque becomes a daring building due to its single boundary[22], a revolutionary one with respect to its structural uniqueness[23], and a courageous innovation since the broad arches rising from four supporting piers render this structure one of unfilled stone work[24]. One may easily claim these properties to be innovative reflections in architecture, and they result in a functional property: light.

> The four walls of the Edirnekapı Mihrimah Mosque are streched between four corner walls, lending minimal support. There is as much window space as there is wall, thus taking voids in the masonry to the limit of structural possibility. This means that the interior is alive with light all day. Other Islamic masonry buildings matched but could not excel this achievement which would only be surpassed in the eighteenth and twentieth centuries.[25]

Architectural historians like Kuban admire the success of Sinan by underlining the brave curtain walls of Edirnekapı Mihrimah Sultan Mosque[26], as well as Belge, who writes with the gaze of an ordinary observer:

> As soon as you enter the mosque, you get surprised again like you did in other works of Sinan. This time, the extra feature is light and one thinks that

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[20] Stephanos Yerasimos, *Süleymaniye*, İstanbul: Yapı Kredi Yayınları, 2002, p. 118.

[21] Kuban, 1987: p. 79.

[22] Erzen, 2004: 87.

[23] Ayda Arel, "Mimaride Görenek, Yenilik ve Mimar Sinan", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri,* Ankara: Türk Tarih Kurumu, 1996, pp. 99-101.

[24] İ. H. Güngör, "The Dome in Sinan's Work", in *Environmental Design: Journal of the Islamic Environmental Design Research Centre,* 1987, p.161.

[25] Goodwin, 1993: 49-50.

[26] Kuban, 2007: 276.

> the architect aimed to grab light intentionally, which yields a bright and spacious interior.[27]

Whoever the observer is, the lighting reaches its peak with this mosque, and another structural cause of this can be understood when the vertical carrying elements of this building are compared with other works of Sinan. The ratio of these elements to the overall area of the mosque is measured as 18% at Şehzade and Süleymaniye Mosques, 14% at Selimiye Mosque and only 12% at Edirnekapı Mihrimah Sultan Mosque[28]. This development also widens the interior space and unifies the central space as mentioned in the previous section and should be respected as a structural innovation of Sinan. However, this can also be interpreted as a result of the mentioned innovation related to the boundaries. As Sinan concentrated on the core baldachin as the main bearing element and used the secondary elements with an organic connection with it, he had the chance to create holes within the walls to place windows.

3.1.3. The Side Galleries

One of the most important contributions of Sinan to Ottoman architecture is the side galleries (or arcades), the first example of which is seen with the Şehzade Mosque (Figure 4). Their structural affect can be best observed in Süleymaniye Mosque, where lateral thrusts are carried gradually to the ground together with these galleries and buttresses. In fact, those galleries are nothing but the secondary boundaries that was mentioned above, which constitutes the source of structural solutions and the main innovation introduced by Sinan. The effective use of those galleries, which play structural, functional and aesthetics role in the building, can also be seen in Selimiye Mosque, where the galleries on the kiblah side are observed for the first time and function as arched buttressing.

> The principal of a hierarchic centralized composition in which the accumulated thrust of composite cover elements would have required enormously thick retaining walls, Sinan's solution, at least for the east and west elevations was to introduce a series of pillars and columns that would alleviate the walls. The creation of galleries on east and west façades, as a new element introduced by Sinan to Ottoman architecture can hence be seen as a major invention.[29]

Not only the structural problem of lateral thrusts provided by buttresses is solved, which had also been one of the critical drawbacks threatening Hagia Sophia, with a clever solution; but these

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[27] Murat Belge, *İstanbul Gezi Rehberi*, İstanbul: Tarih Vakfı Yurt Yayınları, 2000, p.57.

[28] Ali İhsan Ünay, *Tarihi Yapıların Depreme Dayanımı,* Ankara: METU, 2002, p. 73.

[29] Erzen, 2004: 58.

galleries also gives the mosque façade a vivid atmosphere. The mosque resembles civilian architecture examples[30] and these galleries radically alter the simple duality of the wall mass and domed superstructure on the outside[31]. These elements, which are first used by Sinan, are also observed at Sultanahmet and Yeni Valide Mosques and this can also be interpreted as an evidence of innovation, as far as their influence on successor architects are considered. Moreover, Goodwin highlights their originality in Ottoman architecture and relates them with Renaissance façades:

> What had been lacking in earlier Ottoman architecture were the splendid façades of the Western Renaissance and before. Now these appear in embryo along the sides of the mosque in the form of large arcades with a rhythm of flanking arches at each side of their central entrances. (…) The creation of loggias in the Italian Renaissance manner gave the sides of the mosque a new importance which was enhanced by the use of two storeys, each with its own rhythm to its arches.[32]

Furthermore, the fountains, which were situated just beneath these galleries in the Süleymaniye (Figure 5), were being witnessed for the first time in a mosque and their functionality obvious. They were designed for the use of worshipers, who will fulfill their ablution ritual here. In other words, the innovative echoes of those galleries were being observed with these fountains once more.

3.1.4. Finalizing The Dome Structure As A Prototype

If all the contributions of Sinan to Ottoman architecture are evaluated, one should be specially highlighted: Making a synthesis of the dome construction of previous ages and finalizing the dome structure as a prototype for the use of his successors. It will not be wrong to call him a "dome maker" or the "master of domes", since he had covered hundreds of buildings of every scale with domes and perfected this technology by trying several different schemes.[33] As Grabar also points

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[30] Selçuk Mülayim, *Ters Lale: Osmanlı Mimarisinde Sinan Çağı ve Süleymaniye*, İstanbul 2001, p. 193.

[31] Doğan Kuban, "The Style of Sinan's Domed Structures", in *Muquarnas: An Annual of Islamic Art and Architecture*, Vol.4, Leiden-E.J. Brill, 1987, p. 79.

[32] Godfrey Goodwin, *Sinan: Ottoman Architecture and its Values Today*, London: Saqi Books, 1993, pp. 35, 37.

[33] İ. H. Güngör, "The Dome in Sinan's Work", in *Environmental Design: Journal of the Islamic Environmental Design Research Centre,* 1987, p.156. The following astimationis given here: "Sinan has the distinction of having built or restored a total of over 10,000 domes and cupolas on a total figure of 344 or 477 structures, and holds the record for stone and/or brick domes, a record which it is hard to imagine will ever be surpassed." Güngör also describes the reasons for Sinan's record in the same page as follows: "Sinan concentrated mainly in the second part of his career on perfecting his theoretic skills as well as evolving them and creating the technolgy to realize his innovative ideas."

out, what Sinan had really done was to take the ideas of the dome-baldachin and of the dome membrane to their most extreme point of growth.[34]

Kuban's article on the evolution of Sinan's domed structures investigates the way Sinan had followed to reach the perfection of the Selimiye.[35] This perfection should not be understood as only the accomplishment of the best bearing system supplying the unification of auxiliary parts around the central space; it also means the purification of the exterior view which gives a monumental impression.

> The lesson to be learned from the Selimiye is that an architectural element with distant symbolism can become generator of a design without being formally emphasized. This is what makes Sinan's style the purest domical style in the history of architecture. It is the apotheosis of the primitive idea of a domical hollow as shelter.[36]

Güngör's detailed work on Sinan's domes gives an almost complete reference for different types of dome support systems with illustrative and comparative examples. He derives that, the dome in a work of Sinan, is not simply a covering; more than a mere super structural element over space, it complements the space. Güngör argues that, Sinan treats the dome as the most important spatial element, so in creating different spaces he chooses to reposition the dome in relation to the general mass of the structure.[37] As a result, he uses the word "innovative" several times while describing Sinan's solutions, which can also be used to summarize the ideas of different architectural historians:

> Sinan's long experiments with the key elements of domed structures, namely the dome, pendentive and support members provided him with the facility to evolve a synthesis of these elements in a totally rational structural support system which was both the ultimate solution and at the same time relatively uncomplex in conception.[38]

In fact, Sinan's contributions to architecture were not technically novel. The construction technology, the construction of dome as well, was almost the same for centuries. However, Sinan's success was the sum of his singular solutions for structural problems, together with the aesthetic and

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[34] Oleg Grabar, "The Meanings of Sinan's Architecture", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri*, Ankara: Türk Tarih Kurumu, 1996, p.351.

[35] Kuban, 1987: 72-97.

[36] Ibid. p. 91.

[37] Güngör, pp.156-167.

[38] Bülend Özer, "The Architect of Domed Mosques as a Master of Pluralism", in *Environmental Design Journal of the Islamic Environmental Design Research Centre*, 1987, p.155.

functional excellence. Moreover, he was not satisfied with the most logical solution of Şehzade Mosque, for example; he was in search for a spatial order which suits best with the structure. His ultimate aim was not even constructing the largest dome; this would make him a simple engineer.[39] Instead, he created a building like Selimiye finally, which can be interpreted as the uttermost political expression of mosque symbolism in Ottoman architecture.[40] Yet, mosques which had to be built with smaller domes for lesser dignitaries of the empire also have interesting solutions for creating an impressive structural and spatial organization.[41] Sinan's approach to structure as the elementary element, using the double boundary system effectively and the importance that he gave to the aesthetic value of the structure resulted in this variety. All of these constitute the answer for the innovation in his works. Therefore, we may regard his finalizing of dome structure to form a prototype, to which his successors adhered even today, as a crystallization of his innovative efforts.

3.1.5. Combining The Architectural Space With The Bearing System

In almost every era of the architectural history, it was a difficult task to combine a cube with a sphere by solving the tensions between these two different geometric forms. But for Sinan, this became the sign of his genius and artistic talent in every new building. Moreover, his buildings were very distinctive due to the relation between the interior elements and the exterior impression. One can easily imagine the atmosphere of within from the outside, and similarly, the outer shape can absolutely be guessed as one wanders inside. This effect was the result of the skillful combination of space to be covered and the elements that cover.

Such a combination observed in Piyale Paşa Mosque was regarded as innovative by Özer, in the sense that the structural elements, for example the buttresses, are expressed on the exterior and the pendentives being particularly visible on the outer shell.[42] This harmony is also highlighted by Güngör, by regarding the structure itself as a total reflection of its dynamism, that is, the relationship between internal space and structural mass or positive-negative space.[43] He also points that Sinan had used buttress towers together with the innovative features of introducing pilasters to enhance the moment of inertia in supporting members. Therefore, by thinning the walls where lower forces were

[39] Kuban, 2007: 261.

[40] Ibid. p. 468.

[41] Erzen, 2004: 82.

[42] Ibid, 149.

[43] Güngör, p. 156.

acting, thus economizing structurally and providing the building with a greater elegance, Sinan's structures become translucent.[44]

Erzen also emphasizes that one of the fundamental design problems of Ottoman architecture was floor planning or integrating the building structure with the covering system.[45] And she describes the approach of Sinan for solving this problem as follows and this can be regarded as an innovation:

> Sinan's fundamental plan arrangements of his buildings were not different when compared with traditional schemes. Therefore, the main reason for the distinctiveness of his buildings was the order of the covering system that these schemes determine and the order of the bearing system. The changes that will be made within the covering system should be balanced with the ones within the bearing system. Hence, the plan and cover should be handled together.[46]

3.1.6. Criticism of Hagia Sophia

Süleymaniye, the imperial mosque of Süleyman the Magnificent, is compared with Hagia Sophia by several authorities and the work of Sinan is admired by many of them. For instance, Gülru Necipoğlu Kafadar gives the following evaluation:

> Sinan's eclectic borrowings were given unity by the Süleymaniye's central theme, which has been aptly defined as a 'structural criticism' and 'rationalization' of the Hagia Sophia's scheme with a new spatial definition. The mosque's support system skillfully counterbalances the lateral thrusts of the domical superstructure, and the side aisles are blended with the central baldachin to avoid Hagia Sophia's illusory effects spatial ambiguity.[47]

The title of this section, in fact, is borrowed from Rowland Mainstone, who gives a deep comparison of two great buildings, Hagia Sophia and Süleymaniye, in his book "Structure in Architecture: History, Design and Innovation". He closely examines the changes made by Sinan, which can be evaluated as constructive criticism[48]. He interprets Sinan's departure from the tradition as using the same means in a more purposefully selective manner so that they make the fullest

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[44] Ibid.

[45] Jale N. Erzen, *Mimar Sinan Cami ve Külliyeleri: Tasarım Süreci Üzerine Bir İnceleme*, Ankara: METU, 1991, p.14.

[46] Ibid.

[47] Gülru Necipoğlu Kafadar, "The Emulation of the Past in Sinan's Imperial Mosques", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri,* Ankara: Türk Tarih Kurumu, 1996, p.183.

[48] Rowland Mainstone, Structure in Architecture: History, Design and Innovation, Norfolk: Ashgate Publishing, 1999, pp.351-359.

contribution to his ultimate object. Therefore, such a critic of previous works and perfection of them should be regarded as pure innovation.

In an earlier book, Mainstone also points a possible mistake when a comparison is being done between these two buildigs. He states that they cannot be compared architecturally, since the aim of the latter was to create just one unified space within, with any aisles and galleries either brought fully into this space or reduced to a very minor role indeed[49]. Stepping further with a detailed comparison of Hagia Sophia and Süleymaniye helps one to understand the innovations realized by Sinan in a better way. But Mainstone's statement should be kept in mind and a structural comparison should be preferred instead of an architectural one. Moreover, one should not fall into the mistake of Diez, who states that a style cannot be imitated by borrowing the constructive scheme[50]. In fact, the two buildings quite differ both in appearance and structure, but only share similar structural elements.

> Sinan, did not imitate the Hagia Sophia scheme in any of his mosques - maybe, except Kılıç Ali Pasha Mosque. After a thousand years, he did not use once again a problematic covering system, which has collapsed three times. Hence, the misunderstanding of Diez and some European art historians arose from regarding the semi-dome as a fundamental structural form, instead of a structural element and neglecting the development of space in Ottoman mosque design for a hundred years.[51]

After paying satisfactory attention to this comparison, one easily distinguishes the ultimate result of the mentioned criticism: Unification of the central space. And this result was the main goal of the mosque construction in the Islamic world for centuries. However, Süleymaniye becomes the subject of a comparison within the aesthetic criteria and the work of Sinan creates a new architectural value. The bulky mass of Hagia Sophia was improved to a sculpture-like monumental building and its beautiful formation is admitted by many architectural historians:

> The Süleymaniye realizes Mehmed II's unfulfilled ambition to create an Ottoman style mosque matching Hagia Sophia in magnificence with its refined proportions, its harmonious pyramidal cascade of varied domes and half-domes, its internal galleries resting on precious arched colonnades, and its lateral façades embellished with lavish superimposed arcades.[52]

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[49] Rowland Mainstone, *Developments in Structural Form*, Cambridge: MIT Press, 1973, p.206.

[50] Ernst Diez, *Türk Sanatı, Başlangıcından Günümüze Kadar*, İstanbul: 1946, cited in D. Kuban, *Osmanlı Mimarisi*, İstanbul: YEM Yayın, 2007, p.17.

[51] Kuban, 2007: 17

[52] Gülru Necipoğlu Kafadar, *The Age of Sinan: Architectural Culture in the Ottoman Empire*, Princeton and Oxford: Princeton University Press, 2005, p.102.

To sum up, quoting from Erzen may give a more precise understanding of both structural and aesthetic criticism brought to Hagia Sophia with Süleymaniye by Sinan, which yields innovative results:

> Although Süleymaniye's structural scheme is reminiscent of the Hagia Sophia, the way the eastern and western parts of the structure are integrated to the whole, achieving a rich effect of spatial movement and transparency, as well as lighting, show an altogether different intention. With the use of alternating domes on the east and west sides, Sinan achieves the same spatial expansion as would be provided by a half dome, yet with a lighter and more dynamic structure. On the other hand, with this scheme, the corner domes are better connected with the rest of the encircling spaces, heightening the effect of continuity and spatial flow.[53]

3.2. Non-Structural Innovations Realized by Architect Sinan

In this part of the study, the developments realized by Sinan, which introduces innovative solutions to the problems mostly related to function, form and plan, are listed within seven headings. It should be noted that, almost all of these solutions also contain aesthetic perfections, although they can not be classified as purely functional or aesthetic. On the other hand, in the last part of this section, Sinan's continuous search for new forms are admitted as a research and development activity and evaluated within this context.

3.2.1. Establishing Building-Site Relations

Another distinguishing aspect of Sinan's works is easily seen in the harmony of his buildings with the topography. It is well known that the topographical difficulties, such as slopes, transforms into advantageous impressions in Sinan's works. Nevertheless, such a transformation requires a good engineering knowledge and innovative solutions peculiar to each building.

The land features of İstanbul and the size of construction area forced Sinan for such solutions in several large complexes. However, the results were innovative and highly appreciated. Goodwin finds his adaptation of the Sokollu complex at Kadırga (Figure 6) to such demands "a dynamic example of his genius."[54] Kuban also highlights the same building:

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[53] Erzen, 2004: 81.

[54] Godfrey Goodwin, "Sinan and City Planning", in *Environmental Design: Journal of the Islamic Environmental Design Research Centre*, 1987, p. 13.

> Constructing the magnificent portico arcades and courtyard of Kadırga Sokollu Mosque on such an inclined area required a buttressing wall. (…) Situating the building complex on this area, where there is an elevation difference of 5 meters between the main gate and the courtyard, and 4 meters between this courtyard and the dervish lodge behind, shows Sinan's proficiency in establishing building-site relation, which we also witness at Süleymaniye, Zal Mahmud Paşa and Üsküdar Mihrimah Sultan Mosques.[55]

The relation between the elements of these complexes also represents a vivid form, which may be called organic, rather than geometric. This liveliness, which can be seen as the result of the architect's genius, derives from the fact that the uneven topography is left as it is and is used to create a three dimensional relation amongst the varying buildings and spaces of the complex.[56]

On the other hand, Sinan's mastery in establishing building-site relation can also be observed when the special case of the building requires an elevation difference, such as the one in Azapkapı Sokollu Mosque and Rüstem Paşa Mosque. Those buildings rise on a platform due to the functional needs of supplying space for commercial use beneath the mosque or to prevent moisture, but the solution is innovative for both cases since the adaptation of the building is quite skillful although the area is risky for building:

> Like Rüstem Paşa's Mosque across the waters, Azapkapı Sokollu Mosque rises on a massive, vaulted precautionary substructure adapted for commercial use. Sinan, ever reliable engineer, plays safe in assuring its stability on a site of dubious soil-bearing capacity.[57]

3.2.2. A Novel Design I: Site Organization and Urban Planning

Sinan's contributions to Ottoman architecture could also be appreciated as far as his approach to urban planning and site organization with his works have developed the cities in a positive manner. Sinan was responsible for every detail of city administration including the sewers, fire regulations and the repair of all public monuments and he drew or supervised the plans of important buildings in the city and all over the empire.[58] Therefore, the placement of the buildings in the cities, their position with respect to each other and the relation they establish with the inhabitants show Sinan's innovative skills in urban planning, too. For instance, it is suggested that Sinan had situated the Selimiye in Edirne in close proximity to Eski Cami and Üç Şerefeli in a spatial dialogue

[55] Kuban, 2007: 320.

[56] Erzen, 2004: 157.

[57] Egli, p. 136.

[58] Godfrey Goodwin, *A History of Ottoman Architecture*, London: Thames and Hudson, 1971, p. 197.

reminiscent of the location of La Salute in Venice.[59] Moreover, he had not only changed the typical form of the mosque but had given new formal meaning to its placement in the city.[60] While considering İstanbul, quoting from Erzen would give a more precise understanding:

> In the Ottoman period, it is Sinan who, overseeing all the architectural activity of the empire, gave it its imperial form and meaning. He contributed to it a mechanism of connections that made it work as a whole. He activated the already existing foundation to function appropriate to an imperial Ottoman capital, by providing the necessary links and aesthetic significances, through his architecture.[61]

If the relationship of the elements forming the külliye complexes is considered, one may also witness functional innovations. For instance, in Kadırga Sokollu and Edirnekapı Mihrimah Sultan Mosques, the madrasa rooms are placed just in front of the mosque around the courtyard. This site organization stresses the functional relation of mosque and madrasa clearly as the students of these religious schools use the mosque frequently. In fact, the architectural achievement of Sinan's külliye complexes lies in the disposition of the whole, that is, in the arrangement and grouping of the various structures.[62]

Another problem of Ottoman architecture, namely "placing the minaret", which is related to both function and form of a mosque, is also solved ingeniously by Sinan and this should be respected as innovation. Kuban says that "Ottoman experience has got rid off the tradition of the minaret's behavior like a separate tower with Sinan by means of inserting it to total composition of the mosque"[63] For instance, in the Şehzade Mosque, as the massive side walls of the Ottoman architecture is replaced by galleries for the first time, the minaret-mosque relation is also established with the help of the side arcades (Figure 7), while this problem was being unsolved for both Beyazıt and Fatih mosques. On the other hand, the aesthetic balance between minarets and the main body of the mosque can easily be observed with Süleymaniye (Figure 8 and 9) as the taller minarets are placed between the mosque and the courtyard and the shorter ones on the outer corners of the courtyard. And in Selimiye, the four tall minarets, which also play a structural role with their weights, are placed at the corners to stress the main dome (Figure 10). As Tayla also states, "Sinan, who comprehends the importance of minarets within the architecture of a mosque and the urban

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[59] Behruz Cinici, "The Urban Arrangement of Selimiye Mosque at Edirne", in *Environmental Design: Journal of the Islamic Environmental Design Research Centre*, 1987, p.86.

[60] Jale N. Erzen, "Sinan as Anti-Classicist", in *Muqarnas*: An Annual of Islamic Art and Architecture, Vol.5, Leiden: E.J. Brill, 1988, p. 70.

[61] Erzen, 2004: 179.

[62] Ulya Vögt-Göknil,. "Spatial Order in Sinan's Külliyes" in *Environmental Design: Journal of the Islamic Environmental Design Research Centre*, 1987, p.168.

[63] Kuban, 2007: 457.

silhouette, used this in his works with a stunning effect"[64] Smaller works of Sinan also find clever solutions for the placement of the minaret. For instance, the minaret is placed in the middle of the entrance in Piyale Paşa Mosque (Figure 11) while it is linked with the mosque with a exuberant arched structure to resolve this old problem[65] in Azapkapı Sokollu Mosque.

3.2.3. A Novel Design II: Contribution To The Urban Silhouette with Sculpture Like Buildings

The coverage of this section may be accepted as the least related developments to be considered as innovations due to the aesthetic emphasis they contain. However, defining innovation in architecture includes intersections with purely creative developments in some cases and both expressions given in this heading also reflect the innovative capability of the artist of our concern, Sinan.

If the religious restrictions of the Ottoman Empire, such as banning of sculpture, are remembered, one may easily deduce that Sinan has surmounted such limitations by transforming his works into sculpture-like monuments. His works' artistic success is appreciated by several architectural historians in that manner. For instance Necipoğlu says that "with a novel sculptural dynamism and plasticity, Selimiye's lofty lateral façades that counterbalance layered horizontal tiers by vertical continuities inaugurate a new chapter in Sinan's mosque design, characterized by transgressions of the classical code."[66] Kuban also describes the plasticity of his works as follows: "He did not have a taste for the modular use of column orders. Having rejected this kind of convenient regularizing element, he had to develop a dynamic arrangement for the façades and achieve plasticity, not by the shape of the individual elements, but by the totality of the building."[67] Therefore, Sinan's novel designs making the form and elevations of his works distinguishable could be regarded as innovative.

On the other hand, Sinan's contribution to the urban silhouette can be regarded as a matter of consensus.[68] For instance, Erzen uses the phrase "Sinan's İstanbul"[69] as Sinan's activity spanned the reign of three Sultans and Kuban states that "Sinan, who is the creator of the architecture of the

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[64] Hüsrev Tayla, "Sinan Minarelerinin Mimaride ve Şehircilikteki Yeri", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri,* Ankara: Türk Tarih Kurumu, 1996, p. 62.
[65] Egli, 1997: 138.

[66] Necipoğlu, 2005: 103.

[67] Kuban, 1987: 79.

[68] Mustafa Cezar, *Osmanlı Başkenti İstanbul*, İstanbul: Erol Kerim Aksoy Kültür, Eğitim, Spor ve Sağlık Vakfı Yayınları, 2002, p.130.

[69] Erzen, 2004: 179.

Empire at its most powerful and rich era, is also the creator of Istanbul's urban physiognomy during the reigns of Kanuni, Selim II and Murat III.[70]" Tayla also appreciates him as follows: "Sinan has chosen the places of his mosques so as to contribute and give way to the development of a city. Moreover, he designed his minarets both comprehending their architecture and their role in the silhouette of the mosque.[71]

In fact, Sinan's success in creating the urban silhouette could easily be witnessed with a single work: Süleymaniye. The monumental perception of this building from several points of the city is unique and the placement of the minarets at the corners of the courtyard together with the waterfall impression created by the domes transforms a religious building into a huge sculpture (Figures 8, 9 and 12). This mosque also establishes relations with other works of Sinan as an observer in Süleymaniye can see the other buildings of him distributed in the city, and with its environment in all four dimensions, as Erzen describes:

> The approach from the harbor had a view of its east elevation, the approach from the west between the colleges was aligned with the mosque's side entry, the southern limits were defined by the cemetery walls. A radial spreading of its dependencies out from the core gradually integrates the complex and its environment.[72]

Moreover, the smaller mosques of Sinan, which are ingeniously and intentionally placed at the shores of the Golden Horn and the Bosporus, such as Zal Mahmut Paşa, Azapkapı Sokollu, Rüstem Paşa, Kılıç Ali Paşa and Şemsi Ahmet Paşa, form the overall scenery of the city, together with the dominating Şehzade and Süleymaniye Mosques. Therefore, Sinan's contribution to the silhouette of a city should also be regarded as innovative as Goodwin also underlines his success in finding solutions to problems in the plan of Süleymaniye:

> With the vision of genius, he did not raise the whole complex on a platform but let the colleges on the Golden Horn side of the mosque and the royal sepulchres descend the steep slope step by step and so not obscure the monumental view, which still survives from Galata and elswhere down the shores of the Horn.[73]

3.2.4. Bridges and Aqueducts

[70] Kuban, 1998: 27

[71] Tayla, 1996: 70.

[72] Erzen, 2004: 184.

[73] Goodwin: 1987, 10.

Together with the public kitchens, hospitals and hostels as part of külliye complexes and other civilian buildings like public baths, Sinan gave examples of buildings which have social and economic benefits, such as bridges and aqueducts. Nevertheless, the form of those buildings was containing several novelties together with their engineering success, and could be regarded as innovative. Therefore, bridges and aqueducts, two of the major heritages of Sinan, will be evaluated within this scope.[74]

Although Sinan has started to be called "master" after gaining a vast structural experience by delivering the waters of Kağıthane River to İstanbul[75], the techniques he had used was not new to architecture. However, Kırkçeşme water conveyance system, which was consisting of several aqueducts, pools and channels[76], was one of the most important structures giving Sinan the title of "the great engineer", as these utilitarian buildings, especially the Mağlova Aqueduct, which was connecting two hills with a sculpture like impression (Figure 13), were as valuable as his great mosques with their design quality.[77] Çeçen also highlights this aqueduct as "a great engineering work which includes novelties" and states that it has several openings to resist torrents and piers with sharp extensions to prevent corrosion.[78]

Another important work of Sinan, namely Büyükçekmece Bridge, has also a unique form (Figure 14), besides its appreciated construction. It was built with stone foundation situating on wooden piles by taking the advantage of small islands, extents 635 meters, and its design combines creative artisan work with skillful engineering.[79] Therefore, this work should be respected as innovative together with aqueducts and other utilitarian buildings of Sinan, as Erzen also point out its importance among other works of Sinan:

> His bridge over the Büyükçekmece Lake which is still intact is his only structure where he has put up a plate inscribed by his signature. It is an

[74] Rogers indicates that "the scope of Sinan's impact upon the urban development of İstanbul is also apparent in the construction of the water supply of Süleymaniye." (J. M. Rogers, "Sinan As Planner: Some Documentary Evidence", in *Environmental Design: Journal of the Islamic Environmental Design Research Centre*, 1987, p. 179) Therefore, such works can also be regarded as an extension of urban planning and appreciated within this context.

[75] Kuran, 1986: 244.

[76] Kazım Çeçen, *Mimar Sinan ve Kırkçeşme Tesisleri*, İstanbul: İstanbul Büyükşehir Belediyesi İSKİ Genel Müdürlüğü, 1988. In this book, detailed explanations of the system is given with numeric values of the elements constituting the system.

[77] Kuban, 2007: 258.

[78] Kazım Çeçen, "16. Yüzyılda İstanbul'da Yapılan Su Tesisleri", in *II. Uluslararası Türk-İslam Bilim ve Teknoloji Tarihi Kongresi, Vol. II: Architect Sinan*, İstanbul: İTÜ Research Center of History of Science and Technology, 1986, p. 111.

[79] Kuban, 2007: 346.

impressive bridge where structural and aesthetic purposes integrate to create both rhythm and solidity.[80]

3.2.5. Other Specific Innovations

One may also witness several innovative approaches in the details of Sinan's works, which solves problems of function, form or plan. For instance, the situation of the muezzin *mahfel* of Selimiye Mosque can be regarded as an innovation as far as its functionality is considered. This placement enables propagation of the voice of imam by muezzin to the rear sides of the mosque more efficiently. Günkut Akın's work[81] concentrates on its symbolism and also underlines its effect on the practical use and uniqueness. Aptullah Kuran also stresses its clever placement that does not yield any symmetry problems, which were observed in other mosques.[82]

Similarly, another important property of Sinan's Mosques, especially the imperial mosques, is their acoustical perfection. Kayılı's several studies cast light on this property of those buildings and he deduces that acoustical performances of the mosques were planned before construction and these performances were results of detailed estimations and design.[83] Cavity resonators, which are empty tubes placed upside down in the dome structure (Figure 15), are discovered in the domes of Sinan's mosques, namely Şehzade, Süleymaniye (Figure 16) and Selimiye, and these are also valued as novel solutions for the sound problems of domed structures by Mülayim[84], which can also be interpreted as an innovation.

Erzen also points two innovations observed in details, which is related to the plan of the mosques and where he manipulates space and volume. She states that Sinan's use of galleries in relatively small hexagonal buildings' interiors, each of which is executed with varying arrangements of supporting columns, represents an innovation in his interior organization.[85] Moreover, Erzen maintains that the development of the mihrab apse also reflects a new interest in treating the volume of the building in the round and regards it as a a final step in the development of façade articulation in Turkish religious architecture.[86] Kuban also respects this articulation as a functional development realized by Sinan as it supplies the octagonal symmetry of the plan.[87]

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[80] Erzen, 2004: 171.

[81] Günkut Akın, "Edirne Selimiye Camii'ndeki Müezzin Mahfili Üzerine Düşünceler", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri,* Ankara: Türk Tarih Kurumu, 1996, pp.27-37.

[82] Kuran, 1986: 169.

[83] Mutbul Kayılı, "Sinan's Acoustical Technology", in *Uluslararası Mimar Sinan Sempozyumu Bildirileri,* Ankara: Türk Tarih Kurumu, 1996, pp.171-175.

[84] Mülayim, 2001: 250.

[85] Jale N. Erzen, "Sinan as Anti-Classicist", in *Muqarnas: An Annual of Islamic Art and Architecture,* Vol.5, Leiden: E.J. Brill, 1988, p.77.

[86] Ibid., p.78.

Lastly, another original solution in plan and function is witnessed in Piyale Paşa and Azapkapı Sokkullu Mosques of Sinan, besides other innovative contributions like the placement of minaret:

> Another feature unusual for this type is the placement of the entrance; two doors arranged symmetrically flanking the main axis, rather than a single door on the main axis. (…) It serves to take weight off the sanctuary axis, to provide those entering the mosque with an unusual perspective on the interior, and to make circulation to and from the prayer-hall less disturbing.[88]

Egli also points out the importance of two entrances and higlight the omitted traditional arcade or portico[89], which should also be regarded as another innovative solution as far as the limited area of the mosque is considered.

3.2.6. Endless Attempts: A Life Long Research and Development

Sinan's endless attempts of new system analysis in each of his buildings can be regarded as a life long research and experimental development activity, and as it is stated in the appendix, the Frascati Manual points out such activities as innovative. If one only concentrates on his mosque designs, experiments for passing to the sphere from a cubical form with different bearing system combinations together with fairly new plans should be respected as innovative steps. With each mosque, Sinan tries to develop his most important innovation, namely double boundary system which was argued in structural innovations part, applies new plans suitable with the topography and new forms and elevations reflecting his aesthetic excellence, and is accordingly called an "anti-classicist":

> Every mosque Sinan built in his fifty-year career testifies to his passion for creating original form. The particularity of each of his mosques is undoubtedly one of the reasons why his architecture is treated in terms of discrete buildings rather than as an oeuvre representing architectural language in the process of being formed. In spite of the variety in the formal expression found in every Sinan mosque, however, a coherent line of development can be discerned through the concerns that all of his mosques have in common.[90]

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[87] Doğan Kuban, *Sinan'ın Sanatı ve Selimiye*, İstanbul: Tarih Vakfı Yurt Yayınları, 1997, p. 137.

[88] Özer, 1987: 149.

[89] Egli, 1997: 137.

[90] Erzen, 1988: 70.

As well as Erzen, Kuban also highlights Sinan's most important contribution to history of architecture as his investigations on domed structures and the final form that he gave to their spatial compositions with Selimiye's perfection.[91] He maintains that Sinan's novel solutions for the primary requirement of Ottoman architecture, namely creating a central unified space, makes him a distinguishable creator.[92] Similarly, Güngör says that "without reducing his structures to type, Sinan was concerned with finding a different structural solution for buildings even of the same dimensions, which indicates his architectural approach and technical mastery."[93]

4. Conclusion

Throughout this study, the basic aim was to reveal and prove the principal innovations in Sinan's art. The primary concentration was on structural innovations, however, other innovations, which are mostly related with function, form and plan, were also classified and listed. For this classification, relevant literature claiming innovations realized by Sinan was searched and they were interpreted with the basic architectural and formal criteria.

Sinan's architecture is known to be functional based on a comprehendible geometry, plain and rational with its fundamental forms; and he is even called the Euclid of his age, as a master architect-engineer in manipulating geometry.[94] His work is considered as the climax of the classical period[95]; even he is uttered to change the course of Ottoman architecture by transforming the classical period into the baroque.[96] Besides, Necipoğlu says that "whatever models he may have used, Sinan's breakthrough in centralized mosque design profoundly transformed and concealed his sources of inspiration by unrecognizably filtering them through the lens of canonical Ottoman architectural forms"[97] while Kuban makes the following evaluation:

> Sinan's architectural form can be summarized as follows: His vocabulary is traditional, but his syntax and grammar are not. For example, although his use of decoration is essentially derived from his predecessors, he thoroughly subordinates it to the architecture. Within the traditional vocabulary of decoration, the most Islamic of all characteristics, Sinan is a pure

[91] Kuban, 2007: 327.

[92] Ibid., p. 462.

[93] Güngör, p. 157.

[94] Kuban, 2007: 465.

[95] Goodwin, 1971: 197.

[96] Erzen, 1988: 82.

[97] Necipoğlu, 2005: 103.

> architectural stylist. Geometrical purity of structural form reached its limits in his work; a single domed baldachin becomes the generator of the entire interior and exterior configuration.[98]

Such evaluations of Sinan's revolutionary style reflect his approach and highlight his innovative source: synthesis of previous forms with structural criticism and aesthetic perfection. In fact, one should look for his innovations in the progress of creating new typologies by means of handling structure as the main criterion, which is followed by functionality and the aesthetic. Accordingly, this study concentrated on the structural novelties of his buildings, indicated the innovations with examples taken form his works and also cast light on other innovative developments.

Lastly, it should be stated that Sinan's impact was global and long lasting. His buildings are compared with his Renasaince contemporaries frequently. For example, Goodwin compares Selimiye Mosque with St. Peter's Church in Rome due to its revolutionary effects.[99] Moreover, his smaller scale buildings such as Azapkapı Sokollu Mosque are evaluated to be better when compared to similar planned buildings such as Santa Maria della Passione or Legnano da San Magno in Milano.[100] On the other hand, his successors continued to adhere to Sinan's plans and solutions. For instance, Yeni Mosque and Sultan Ahmed Mosque take Şehzade Mosque of Sinan as their guide while Nuruosmaniye and Nusretiye copies the plan of Edirnekapı Mihrimah Mosque. Therefore, with these consequences and his novel contributions to Ottoman architecture, one may call Sinan an innovator, without hesitation.

[98] Kuban, 1987: 82.

[99] Goodwin, 1971: 197.

[100] Kuban, 2007: 466.

5. Figures

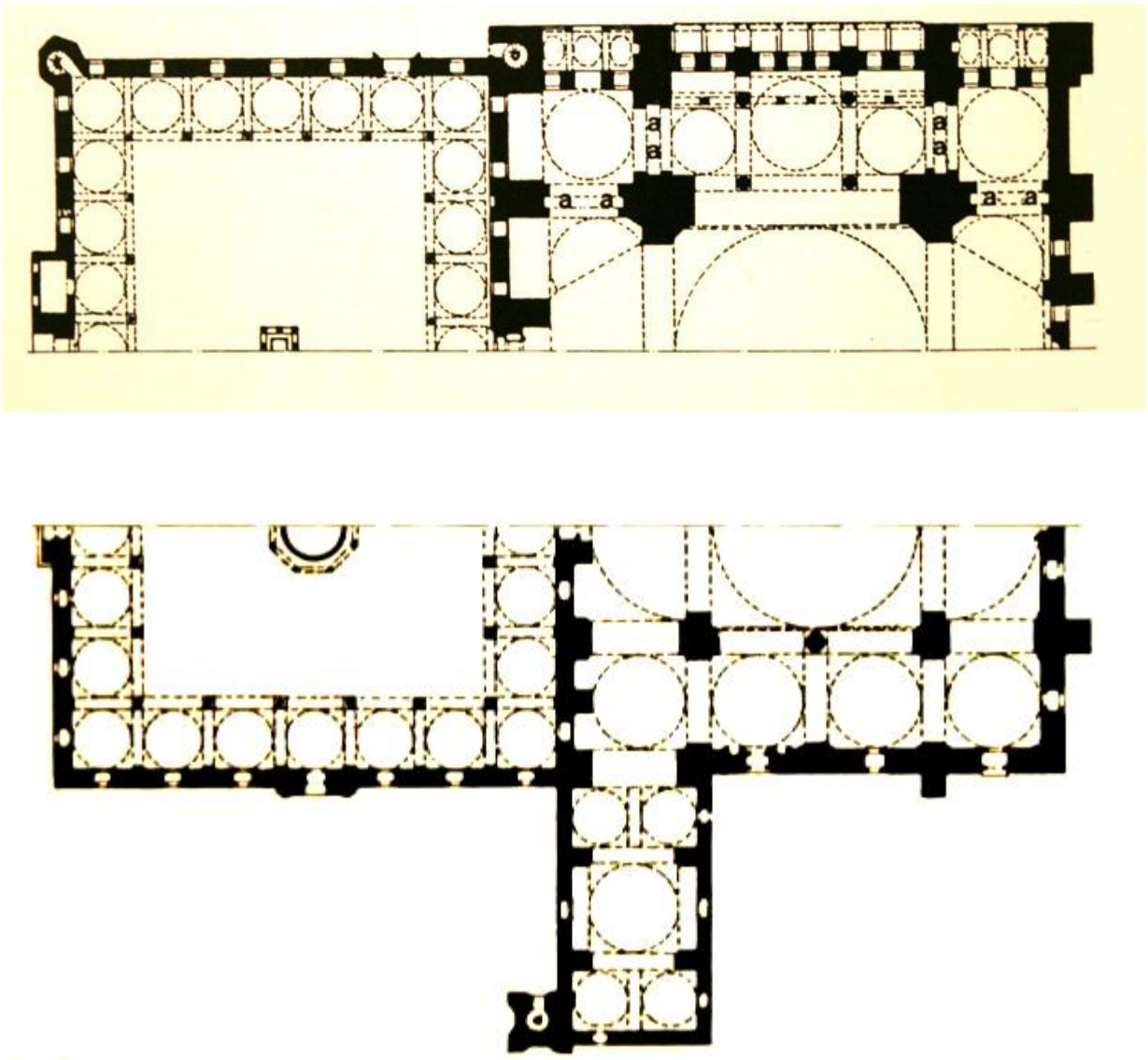

Figure 1 Arch-buttress system in Süleymaniye Mosque (top) plan is indicated with *section aa* and the plan of Bayezit Mosque (bottom), where a double boundary system is lacking, is given in order to clarify the difference. (Source: Rowland Mainstone, *Hagia Sophia: Architecture, Structure and Liturgy of Justinian's Great Church*, New York: Thames and Hudson, 1988, p.250)

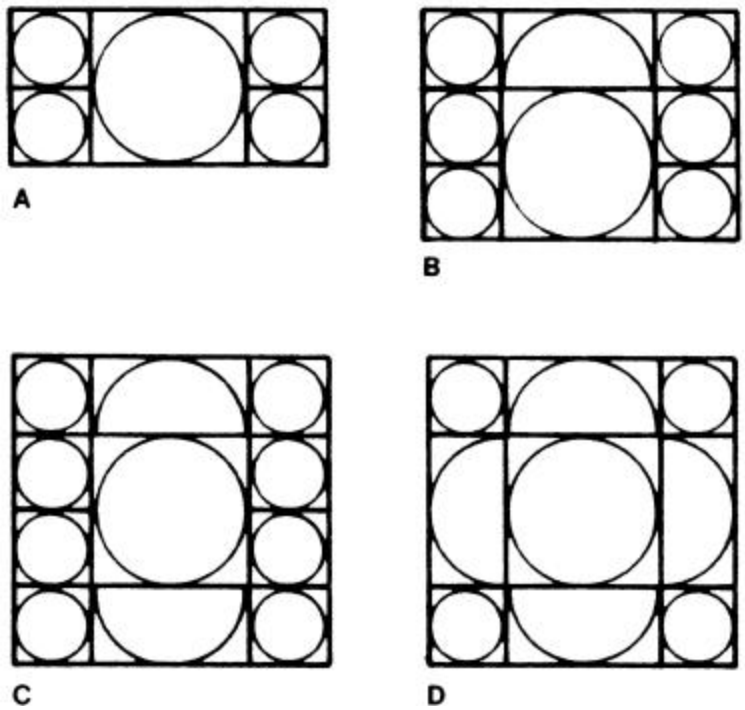

Figure 2 Conceptual development and ideal form reached by Sinan with Şehzade plan. A: Edirne Üç Şerefeli, B: Fatih, C: Bayezit, D: Şehzade (Source: Doğan Kuban, "The Style of Sinan's Domed Structures", in *Muqarnas,* Vol.4, Leiden: E.J. Brill, 1987, p. 83)

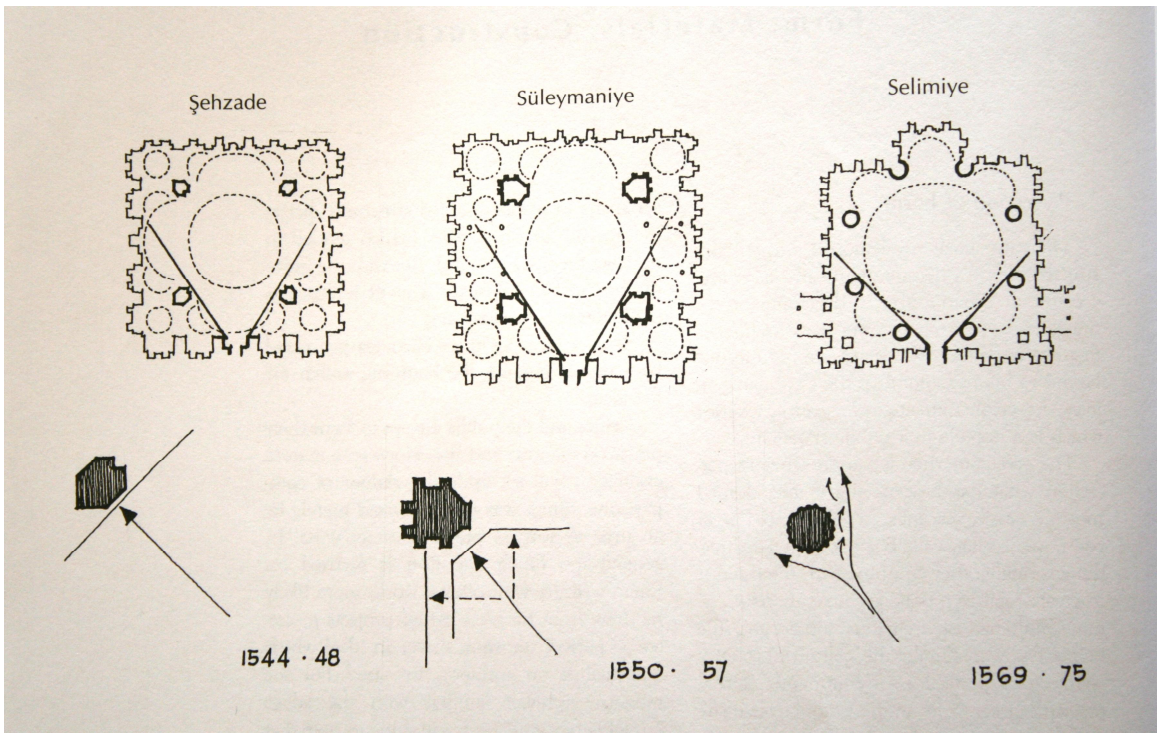

Figure 3 Widening of the field of vision in three sultanate mosques of Sinan; in Şehzade and Süleymaniye 66 degrees, in Selimiye 90 degrees. (Source: Egli, Hans G., *Sinan: An Interpretation*, İstanbul: Ege Yayınları, 1997, p. 176)

Figure 4 The side galleries of Şehzade Mosque. (Photography by M. Özgüleş, 2007)

Figure 5 The side galleries of Süleymaniye Mosque, where ablution fountains were situated beneath them. (Photography by M. Özgüleş, 2007)

Figure 6 Kadırga Sokkollu Mosque of Sinan, which was built on an inclined area. (Photography by M. Özgüleş, 2007)

Figure 7 The minaret-mosque relation established with the help of the side galleries of Şehzade Mosque of Sinan. (Photography by M. Özgüleş, 2007)

Figure 8 Süleymaniye Mosque as seen from the minaret of Şehzade Mosque.
(Photography by M. Özgüleş, 2007)

Figure 9 Süleymaniye Mosque as seen from the shores of Golden Horn.
(Photography by M. Özgüleş, 2007)

Figure 10 Selimiye Mosque, where the main dome is stressed by the four minarets on the corners. (Photography by M. Özgüleş, 2007)

Figure 11 Piyale Paşa Mosque, where the minaret is placed in the middle.
(Photography by M. Özgüleş, 2007)

Figure 12 Rüstem Paşa and Süleymaniye Mosques, as seen from the Galata Bridge.
(Photography by M. Özgüleş, 2007)

Figure 13 Mağlova Aqueduct of Sinan (Photography by J. N. Erzen; Source: Jale N. Erzen, *Sinan Ottoman Architect: An Aesthetic Analysis,* Ankara: METU, 2004, p. 173.)

Figure 14 Büyükçekmece Bridge of Sinan (Photography by M. Özgüleş, 2007)

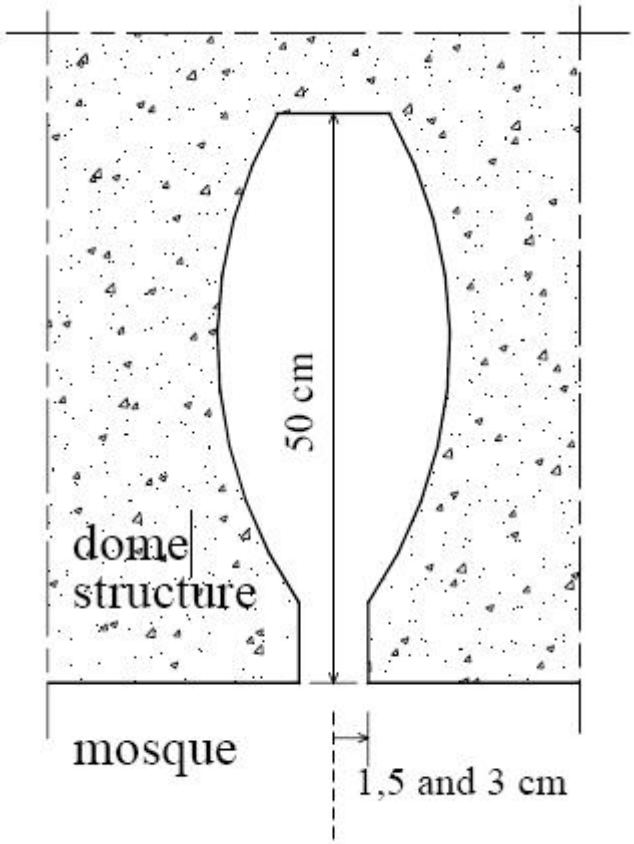

Figure 15 The cross-section of a cavity resonator, which is placed inside the dome structure upside down with its open end looking insight the mosque. (Source: Mutbul Kayılı, "Acoustical Solutions in Classical Ottoman Architecture", in *Foundation for Science, Technology and Civilisation,* ed. Lamaan Ball, Manchester: FSTC Limited, 2005, p. 9)

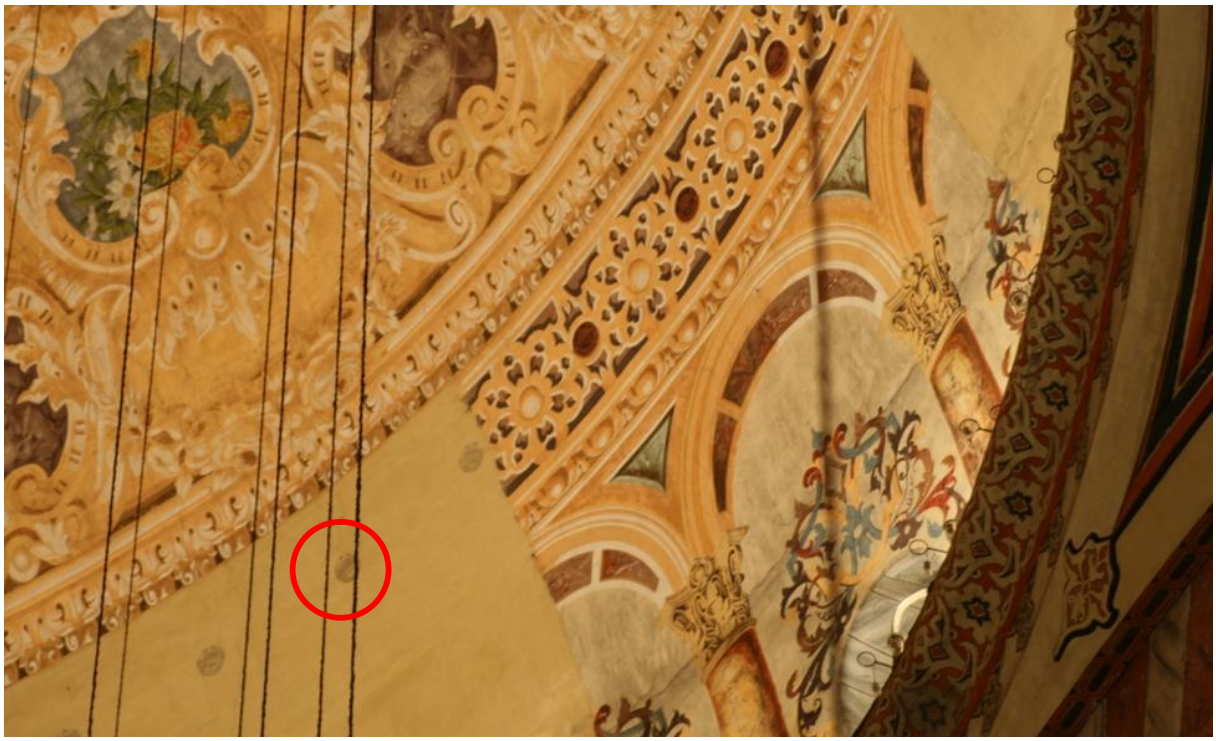

Figure 16 Openings of the cavity resonators, which are observable in Süleymaniye Mosque. (Photography by M. Özgüleş, 2007)

6. Appendix: The Concept of Innovation

The dictionary definition of innovation is given as "the act of introducing something new" in many dictionaries. But for a scientific definition, one should refer to the universal authority, namely the Oslo Manual of OECD[101]. Oslo Manual also designates the boundaries of innovation, which will be beneficial for our concern of innovation:

> The minimum requirement for an innovation is that the product, process, marketing method or organizational method must be *new (or significantly improved)* to the firm. This includes products, processes and methods that firms are the first to develop and those that have been adopted from other firms or organizations.[102]

It must be immediately highlighted that the level of innovation can also be country (mezzo) size or global (macro) size, as well as firm (micro) size, which are mentioned above. When Ottoman architecture is considered, the developments discussed to be innovation or not should be rated at the country level innovation at least, or when the concern is Sinan individually, his novel contributions should be subject to firm level innovation, as he gave his works as the Chief Imperial Architect.

Another important point that should be stressed in this definition is that the criteria for being innovative is not always "being first to develop". In other words, successful adaptations are also regarded as innovation. Moreover, as far as architecture is considered, one should not expect frequent inventive developments since the relevant technology was almost the same for the period of our concern. Therefore, using the word innovation instead of invention will be more suitable for the developments accomplished by Sinan. Lastly, it should also be accepted that there was nothing to invent in building science in the age of Sinan, but a lot to innovate.

Parallel to this evaluation, the second edition of Oslo Manual, which was released in 1997, focuses on the technological product innovation and states that it takes two broad forms, namely technologically new products and technologically improved products.[103] For our concern, the

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[101] OECD, *Oslo Manual: Guidelines for Collecting and Interpreting Innovation Data*, Paris 2005, p. 46. The definition of innovation is given as follows in this last edition: "An innovation is the implementation of a new or significantly improved product (good or service), or process, a new marketing method, or a new organizational method in business practices, workplace organization or external relations."

[102] Ibid.

[103] OECD, *Oslo Manual: Proposed Guidelines for Collecting and Interpreting Technological Innovation Data,* Paris: OECD Publications Service, 1997, p. 32. The definition of technologically improved product is given as follows: "A technologically improved product is an existing product whose performance has been significantly enhanced or upgraded. A simple product may be improved (in terms of better performance or lower cost) through use of higher-performance components or materials, or a complex product which consists of a number of integrated technical sub-systems may be improved by partial changes to one of the sub-systems."

definition of the latter opens the way to pronounce the word "innovation" for every single improvement realized by Sinan; because, his works upgrade previous works of earlier architects. And according to this definition, it is not important whether he did or did not introduce totally new techniques, the performance and influence of his works give adequate evidence for fulfilling the requirements of innovation.

On the other hand, the second edition of Oslo Manual classifies the non innovative changes as "insignificant, minor, or do not involve a sufficient degree of novelty", and "making other creative improvements where novelty does not concern the use or objective performance characteristics of the products or in the way they are produced or delivered but rather their aesthetic or other subjective qualities"[104]. The words "creative improvements" and "aesthetic" may fall into the area where we look for innovation in architecture. However, the manual states that such distinctions are subjective and the final judgment about the nature of the change rests with respondents and/or persons, in the very following sentence. Therefore, the improvements, which are stated for more than once in the related literature, are listed as innovation whether purely creative or aesthetic or not.

Nevertheless, it should be noted that defining and measuring innovation in architecture is not an easy task. However, the use and application of different techniques and materials are regarded as innovative as well as novel designs and structural solutions.[105] Therefore, it would be possible to respect Sinan's developments as innovations as they are fulfilling the second criteria by being original in aesthetic sense and genius in structure.

As far as the history of technology is concerned, the transformation of a wooden axe into an iron one thousands of years ago is accepted as an innovation since its use has resulted in revolutionary changes. Similarly, making of the first clay by imitating use of palm for drinking is also regarded as an innovative step in the history[106]. Therefore the contributions of Sinan in Ottoman architecture should be respected as innovations not only for their novelties but also for their functionalities and later effects.

Lastly, Architect Sinan's endless attempts and his continuous search for new forms could be regarded as an R&D (research and development) activity. Frascati Manual gives the definition of research and experimental development as "R&D comprise creative work undertaken on a systematic basis in order to increase the stock of knowledge, including knowledge of man, culture and society, and the use of this stock of knowledge to devise new applications"[107] and respects this

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[104] Ibid., p. 37.

[105] Alan J. Brooks and Dominique Poole, *Innovation in Architecture*, New York: Spon Press, 2004, p. 2.

[106] Jakop Bronowski, *The Ascent of Man*, Boston: McGraw-Hill, 1973.

[107] OECD, *Frascati Manual: Proposed Standard Practice for Surveys on Research and Experimental Development*, Paris: OECD Publications Service, 2002, p. 30.

as an innovative activity together with other innovation activities stated in Oslo Manual[108]. Therefore, in Section 3.2.6, Sinan's life long activities are evaluated within this context.

[108] Ibid., p. 33.

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