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Categorisation of Persian Mosques by Shape Grammar

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Acknowledgments

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Abstract

In this research, a shape grammar for Persian mosque is developed. This grammar breaks down the geometry of the given plans into their constituent parts and allows these parts to be analysed individually. This shape grammar supplies each plan under consideration a constructive description, that is, a set of operations by means of which the plan could be generated from the initial shape. The shape rules and the classes they defined are the basis for a rigorous and substantial analysis of the formal composition of Persian mosque designs. Moreover, they are used for reproducing the plans. The result provides a classification of Persian mosque plans which is not only precise, but also flexible and by no means restricted to other factors, such as climate, material and so on.

Chapter 1: Introduction

1.1.*Background*

Persian architecture has a continuous history from at least 5000 BC to present. During this long history, monumental Persian architecture has been primarily religious. After the conquest of Persia by the Muslims around 641 AD, Iran became a part of the Islamic world and gradually, Persians became Muslims and artists adapted to the needs of the new religion, Islam. In this period, architecture continued to be a major art form, and mosques became the most important type of building.

Since then, mosques had a special status in the history of Persia. They are the only architectural function that Islam introduced to Persia and during centuries, they served as the principal social and ideological centres in towns and villages.

The mosque is the house of God and therefore holy. In Persian culture, the mosque is not only a place of worship, but also a popular meeting place as well as an important urban landmark. Mosques live with people and alter through the time according to the needs and the tastes of the people. Hence, one hardly can find a mosque that belongs to a single historic period.

There are two types of mosques: the local mosque which is smaller; and the main mosque or congregational mosque where the Friday prayer is recited. Congregational mosques were the hubs of the city, important landmarks, and their possession was essential for cities, therefore they were considered as the signs of urbanity through Persian history. They had more important role in the society than local mosques and were used for prayers, social gathering, judging, educating children, and even as a shelter for travellers, strangers and homlesses (Haji-Qassemi ed., 2004b).

Despite the importance of mosques, the Islamic architecture of Persia is a relatively recent field for scholars because few historic mosques have survived through time and even the remains are mostly uncertainly dated, the literary information about them is scanty or difficult to interpret, and their history and evolution is fraught with uncertainty and disagreements. In addition, non-Muslims are strictly excluded from entering these important Islamic buildings. This factor had caused great problems in studying and categorising them in the conventional ways.

1.2. *Motivation*

There is no systematic research about Persian mosques. The existing descriptions of these buildings abound in imagery, metaphor, and similarity, and each text is as unique as each building. In other words, the text does not attempt to place these buildings into a general framework, beyond such broad categories as 'Jame or Congregational mosque' or 'Local mosque', but these categories are of little help in revealing the other factors which underlie the design. On the other hand, their history and their alterations in the course of the time are the key information for studying and categorising them in the conventional ways, and without archaeological studies to lighten their history, architecture has not advanced in studying them.

Therefore, the architecture of Persian mosques has long been considered difficult to study and architectural historians have typically been more interested in tracing sources of influence and technological advances in them than in uncovering and explaining their compositional structure. Therefore, this research tries to study

Persian mosques plans in details for the first time and this will be the primary contribution to knowledge.

The lack of reliable research about Persian mosques on one side, the expertise in the University of Strathclyde were a starting point for studying and classifying them for the first time. In order to accomplish these goals, the researcher's personal knowledge on mosques and Persian architecture were combined with the existing scientific methodologies.

The great difficulty of this study lay in the attempt to classify mosques and their elements without reliable historical information. The existing mosques are ancient, just like cities in where are located. However, there is not enough litrature for studying them in conventional ways. Mosques are primarily social objects. They carry meanings for society in general, and users in particular. But scholars such as Pope (1965), Frishman (1994), Haji-Qassemi ed. (1996, 98, 2004a and 2004b) and Yarshater (2006) have only described them. And in order to avoid the perceptions and criteria of the observer in the present study, the shared characteristics of mosques were studied by shape grammar, rather than texts. In this case, shape grammar is a useful method that helps to move away from intuitive analysis methods toward more structured ones.

1.3.*Objectives*

The aim of this research is to extract the meaning of the architecture of congregational mosques and establish a clear understanding of their characters by studying their plans. It tries to classify Persian mosques and their elements with respect to their formal, functional properties in the degree of generality necessary for any classification system, yet in sufficient detail to distinguish between different mosques.

However, this study does not aim to trace their long history of continuous development, or to establish the motivations in their characters. As mostly the

Persian mosque history is not documented and the mosques are uncertainly dated, therefore reaching a reliable result about their history is almost impossible. On the other hand, the majority of mosques are located in the central Persia which has arid and semi-arid climate. However, the presented Persian shape grammar analysis in chapter five describes all the case studies. This grammar will be verified in the chapter six.

In order to conduct this analysis, eighteen congregational mosques from different parts of Iran were selected. With the exception of some big cities, such as Tehran and Esfahan, cities and towns only possess one congregational mosque which represents the most dominant architecture of that area. Therefore, the analysed case studies represent the architecture across a vast area. The characteristics of these mosques are studied using shape grammar in the fifth chapter.

However, this research will not study contemporary Persian mosque designs. Therefore, Persian mosques built in the 20th century are out of the scope of this research.

1.4. *Structure of thesis*

The work presented in this thesis is divided in seven chapters. A brief description of each chapter follows below.

Chapter one, introduction:

The present chapter explains the main content, motivation, objectives and the structure of this thesis. Here, a brief summary of thesis has been discussed.

Chapter two, methodology:

This chapter briefly summarises the procedure that has been adopted in this thesis. It explains the process of accomplishing the present inquiry.

Chapter three, Persian mosques:

This chapter gives an overview of the existing literature about Persian architecture and Persian mosques. First, Persian mosques have been described and different spaces of the mosque and their functions have been discussed. Later, the history of Persian mosques chronologically has been outlined. Then, brief history of the case studies, their descriptions and their plans will be mentioned. Subsequently, the history of categorisation and categorisation of Persian mosques has been reviewed. The chapter summarises the existing literature about Persian mosques.

Chapter four, shape grammars:

Chapter four briefly describes shape grammar. It gives an overview of its history and outlines different components of shape grammar. In this chapter, the shape grammar applications have been discussed. And finally, different types of shape grammars have been introduced. In this chapter, the suitability of shape grammar for studying Persian mosques is demonstrated.

Chapter five, shape grammar analysis:

Chapter five is the core part of this dissertation. The first of part of the chapter, the case studies and their circulation patterns and the characteristics of mosque plans have been analysed in details. Based on these discussions, shape grammar rules have been developed to produce existing Persian mosques and finally, Persian shape grammar is presented.

Chapter six, implementation:

The Persian mosques grammar is implemented in chapter six and the shape rules are used to reproduce the layouts of case study plans. In this chapter, the Persian mosque shape grammar is verified.

Chapter seven, conclusion:

The last chapter summarises the main arguments of the previous chapters and the most salient points of the study have been mentioned. Finally, some recommendations for further research have been made.

1.5. *Summary*

This introduction demonstrated the need for further investigation about Persian mosques and highlighted the main arguments of this thesis.

As it was mentioned here, existing literature about Persian mosques is not complete. There is no categorisation of Persian mosques and the present study tries to fill this gap, rather to challenge any existing literature.

This research uses shape grammars for studying and categorising Persian mosques and brings these two previously unrelated works together. The following chapters will use the existing literature to give an overview of Persian architecture and Persian mosques. However, before that in the next chapter the process of conducting this research and its various steps will be discussed.

Chapter 2: Methodology

2.1 Introduction

In order to conduct this research, various steps have been taken; this process will be discussed here. This chapter will try to clarify this inquiry and the process of accomplishing it.

2.2 Research question

The present study tries to categorise Persian mosque by shape grammar for the first time. Mosques are the most important types of building in the Islamic countries, including Iran, however, they have been categorised only by their location, age and size and no attempts have been made to study and to categorise them based on their plans.

The limited edition "Cyclopaedia of Iranian Islamic Architecture, Ganjnameh" gives an overview on different types of buildings in Iran, including Persian mosques. This cyclopaedia is a reliable source of information about the Persian mosque plans. But, it has only gathered historic information about mosques in Iran with their photos, plans, and sections, without offering any categorisation or analysis. Different types of buildings have not been categorised but only arranged alphabetically. This

cyclopaedia has been the main source for the plans of the Persian mosques in this thesis.

Therefore, the aim of this research is to study and to classify Persian mosques plans and their elements with respect to their formal, functional properties for the first time. This study aims to be in a degree general which is expected from any classification system, but at the same time, to include sufficient details in order to distinguish between different classes.

2.3   Literature review

This research began with a gap in the existing literatures about Persian mosques, as they are only descriptive and the formal characteristics of Persian mosques have not been studied before. These descriptive literatures are inaccurate and unreliable, as each text is as unique as each building. In other words, these texts do not attempt to place these buildings into a general framework, beyond such broad categories as 'Jame or Congregational mosque' or 'Local mosque', but these categories are of little help in revealing the other factors which underlie each design.

On the other hand, the history of Persian mosques and their alterations in the course of the time are essential for studying and categorising them in the conventional ways, and without archaeological studies to lighten their history, architecture can not advanced in studying them.

The lack of this information has caused the architecture of Persian mosques to be considered difficult to study and architectural historians have typically been more interested in tracing sources of influence and technological advances in them than in uncovering and explaining their compositional structure.

The great difficulty of this research lay in the attempt to classify mosques without this important information. Mosques are primarily social objects. They carry meanings for society in general, and users in particular. And texts are used both to

describe and to prescribe them. But in order to avoid the perceptions and criteria of the observer in the categorisation, the shared formal characteristics of mosques are studied by shape grammar formalism, rather than texts. In this context, shape grammar is a useful method that helps to move away from intuitive analysis methods toward more structured ones.

In this stage, the scheme or research outline was conducted to overcome the difficulties of studying these mosques and to help insure that data were properly analysed and interpreted. In order to do so, the next step in the research process was to become familiar with the recent researches and publications available on Persian mosques and shape grammars. The general purpose of the literature review was to find out the current state of knowledge about these topics. It shows that although some prior work had been conducted on Persian mosques, the identified gap has not been researched before and no attempts have been made to categorise them.

2.4   *Data collection*

After the literature research it had been decided which samples should be used for further investigation, and how to use shape grammars to study them. These decisions were made before any sample elimination.

Great care has been taken when collecting and preparing data, as the data collection process ensures that data gathered is both defined and accurate and that subsequent decisions based on arguments embodied in the findings are valid.

There are two types of mosques: (1) the main mosques or congregational mosques, which is called "Jame" in Persian, is the one where the Friday prayer is recited; and (2) the second type is called "Masjid", which is local, smaller mosques and can seldom be compared to the first type. All case studies have been chosen from congregational mosques.

Eighteen congregational mosque plans were chosen for the purpose of this research. These case studies are within the current borders of Iran. The study was restricted to the analysis of the first floor plans of these mosques. In Table 2-1 the chosen mosques are listed.

Table 2- 1: The complete list of case studies with their location and date of construction

No.	Mosque Name	Location	Construction Date
1	Abhar Congregational Mosque	Abhar, west of Iran	11th century
2	Ardestan Congregational Mosque	Ardestan, central	9th century
3	Babol Congregational Mosque	Babol, north	11th century
4	Boroujerd Congregational Mosque	Boroujerd, west	9th century
5	Chaleshtor Congregational Mosque	Chaleshtor, west	19th century
6	Damghan Congregational Mosque	Damghan, central	7th century
7	Dezful Congregational Mosque	Dezful, south-west	9th century
8	Orumiyeh Congregational Mosque	Orumiyeh, north-west	11th century
9	Oshtorjan Congregational Mosque	Oshtorjan, central	14th century
10	Sabzevar Congregational Mosque	Sabzevar, north-east	11th century
11	Sanandaj Congregational Mosque	Sanandaj, west	19th century
12	Sarab Congregational Mosque	Sarab, north-west	15th century
13	Sari Congregational Mosque	Sari, north	7th century
14	Saveh Congregational Mosque	Saveh, west	9th century
15	Tabriz Congregational Mosque	Tabriz, north-west	16th century
16	Tuyserkan Congregational Mosque	Tuyserkan, west	Unknown before 19th century
17	Zanjan Congregational Mosque	Zanjan, west	19th century
18	Zavareh Congregational Mosque	Zavareh, central	12th century

These case studies will be discussed in the next chapter.

2.5   Data analysis method

Shape grammar is especially useful for analysing buildings with historic background. In shape grammar, a design can be understood, in a syntactic or compositional sense, as a complex of shapes and relationships between these shapes. One way of describing a design would be to say that it is composed of shapes and that these shapes are arranged according to the spatial relation between them. A more complete description of a design can be given by specifying exactly how spatial relations recur in it or how it may be constructed in terms of these spatial relations. A shape grammar does that and therefore generates designs which are syntactically alike as their compositions are governed by the same spatial relations.

The shape grammar formalism is probably the most compelling means now available to represent the detailed understanding of the composition of designs in existing languages of architecture. And once a shape grammar has been developed for a given group of designs, it can be used to generate the designs in the group and new ones in the same compositional style. Such designs allow for the design implications of the rules of composition encoded in the grammar to be explored, and for an informed comparison of the intuitive understanding of a style and its formal definition.

This research is an analytical application of shape grammars and it is intended for a diverse audience from historians to designers who use the grammars for educational purposes in order to understand a particular design.

2.5.1   Data analysis

In the analysis of existing designs such as this study, recognizing spatial relations between shapes occurring in Persian mosque plans provides the foundation for a rigorous, intelligible discussion of formal characteristics and structure of Persian mosques. Then in the synthesis of designs; these spatial relations are the foundation for constructing plans whose formal characteristics and structure are known. Therefore, defining new spatial relations from ones given in an existing language of

designs can be the simplest, most direct and informative way of producing new plans in the existing style.

Criteria for authoring successful analytic grammars were mentioned by Stiny and Mitchell (1978a). Their requirements are that: "(1) it should clarify the underlying commonality of structure and appearance manifest for the buildings in the corpus; (2) it should supply the conventions and criteria necessary to determine whether any other building not in the original corpus is an instance of the style; and (3) it should provide the compositional machinery needed to design new buildings that are instances of the style."

The process of authoring the grammar of Persian mosque plans, based on these criteria was accomplished in five stages:

(1) A vocabulary of shapes in accordance to different mosque plan spaces was specified which provide the basic building elements for analysing and designing Persian mosques.

(2) Spatial relations between shapes in the vocabulary were determined. A spatial relation is specified whenever any collection of shapes is considered to form a recognizable arrangement. Persian mosque plans were understood in terms of their spatial relations. Building elements are arranged in designs according to these spatial relations.

(3) Shape rules were specified in terms of the spatial relations. The structure observed in designs depends on the recurrence of spatial relations used to construct them. The way spatial relations recur was fixed by the shape rules.

(4) Shapes in the vocabulary were considered and combined to form initial shapes. Shape rules apply recursively to initial shapes to construct designs.

(5) Shape grammars were specified in terms of the shape rules and the initial shapes. Each shape grammar defines a language of Persian mosque designs.

2.5.2   Results

Based on a corpus of eighteen mosques from around Iran, the Persian mosque shape grammar is defined. This grammar is used to categorise the Persian mosque plans. By the means of this grammar, one can claim full understanding of the different types of Persian mosques as its rules are easy to understand.

This thesis demonstrates and explains the fundamental characteristics of the Persian mosques through a grammar which is not only correct (since it produces a design with the desired properties), but also convincing (since its rules are remarkably simple).

Based on the conventions governing the spatial organization of Persian mosques, another interesting outcome of this research can be defining precise indicators of the similarities and differences between different mosques types, a methodology that can be extended without difficulty to a larger and more diverse corpus of buildings.

2.6   Summary

In short, this research has been constructed by bringing two different area of interest together, Persian mosque design and shape grammars. In this chapter, the need for further investigation in these apparently unrelated areas was highlighted. This short review showed existing literature about Persian mosques is not fully finished and argued a need for filling the existing gap in the knowledge. At the end, the structure of this thesis was discussed.

The discussion of this chapter is the foundation of the next two chapters, Persian mosques and shape grammars.

Chapter 3: Persian Mosques

3.1   *Introduction*

This chapter summarises the existing literature about Persian architecture and Persian mosques. It starts with a brief introduction. In the next part, different elements of the Persian mosques, such as the different spaces of the plans, their architects and patrons, their architecture, typology, structure, material, climate and the different branches of Islam will be explained. The existing categorisation of Persian mosques will be mentioned too. In the next part, the history of Persian architecture, with the highlights of important events will be discussed; this history has organised chronologically. Finally, the case studies, their criteria and a brief summary of their history will be discussed.

As was discussed, the territory covered in this research is within the present borders of Iran. The name Iran means "Land of the Aryans". Iran was known as "Persia" until 1935, and became an Islamic republic in 1979. It is located in the Middle East, bordering the Gulf of Oman, the Persian Gulf, and the Caspian Sea, between Iraq and Pakistan. It has 1.636 million sq km land, and has borders with: Afghanistan 936 km, Armenia 35 km, Azerbaijan 611 km, Iraq 1,458 km, Pakistan 909 km, Turkey 499 km, and Turkmenistan 992 km (The World Factbook, 2009). Figure 3- 1 shows the

recent map of Iran with important cities and its neighbours. Iran climate is mostly arid or semiarid, and subtropical along Caspian coast.

Figure 3- 1: Map of Iran with important cities (The World Factbook, 2009)

Architecture in Persia has a continuous history from at least 5000 BC to present, with characteristic examples spread over a huge area from Syria to North India and even parts of China. As Pope (1965) described, the Persian architecture has simple characteristics with noble forms richly embellished and in meaning and purpose, monumental Persian architecture was primarily religious; the guiding, formative motif was cosmic symbolism by which man was brought into communication and participation with the powers of Heaven. This theme not only gave unity and continuity to the architecture of Persia but was a primary source of its emotional character as well.

The natural resources available for building vary considerably across the country. Wooden and stone buildings are rare. Heavy clays can also be seen in different parts of Iran. However, brick has been the most popolar building material in the Persian architecture. Despite the variety of materials, Persian architecture has continuity and nonetheless a unique style that could not be mistaken for any other (O'Kane, 1994).

Most structures are simple in mass and contour, conveying from a distance, a spirit of repose and assurance. This combination can be considered as one of the characteristic of the Persian aesthetic experience.

Architectural ornament was almost wholly abstract, excepting only a few figural murals and calligraphic inscriptions, and even these inscriptions are notable as pure design. In most periods (Pope, 1965), ornamentation was used rich and varied in colour, accomplishing an intensity and harmony that have never been equalled. This passion for colour was favoured by the landscape. Much of Iran's landscape for many months of each year is lifeless and boring, only to become in the springtime suddenly radiant with flowers. Therefore the use of floral patterns became a sacred symbol of life and happiness and appeared on every occasion and in every way and it was used to preserve the transient beauty of the garden in a more permanent form (Pope, 1965).

Another important factor in Persian architecture is light. From Zoroastrian – the ancient Persian religion before Islam – times, the beautiful was integrally associated with light. It was an essential component of divine personality opposed in every way to the dark, evil and disorderly. However in a mosque, the poor illumination was not a serious disadvantage as the light would always come from the back of the congregation, thus concentrating on the mihrab and the prayer leader.

In Persian architecture and art, both lightness and clarity are sought. Persian ornament of all periods reveals a basic organisation that is rational and precise. Another important factor in Persian architecture is water. As most of Iran has arid

and semiarid climate, life in Iran depends upon water. It is not only the central factor of living, but also the symbol of life and hope.

The primary task of Persian architecture and its greatest achievements were in the service of religion and through the Persian history, these buildings, both physically and symbolically, tried to bridge the huge gap between the material world and Heaven. Therefore to discuss them separately is not so easy, as they are not always separate and even meant to be viewed together. For example, a mosque was not only a temple and a place of worship, but also a popular meeting point and an urban land mark.

3.2   Persian Mosque

Pride of place among Muslim buildings belonged to mosques, especially the congregational (jame or Friday) mosques that served as the principal social and ideological centres in towns and villages. "Mosque" means merely a place of prostration. A mosque serves both as a house of worship and as a symbol of Islam. Islam originated with the teachings of Prophet Muhammad in the 7th century. Muslims believe he is the final of all religious prophets and that the Quran was revealed to him by God. Obedience to God is a primary theme in Islam.

Although one fifth of the world's population are Muslims, but the architecture of the mosque does not share much unity and varies from one place to another. Generally, the differences in architectural style between Islamic countries are enormous. Therefore, this research only covers the architecture of Persian mosque.

Mostly the plan and the structure of the mosques are simple which reflects the simplicity of Islam. Moreover, as shared worship is at the heart of Islam, the common floor level frequently has no closed doors, no privileged positions and no hierarchy just like Islam (Pope, 1965). Generally, the mosque through its plan and structure declares the Islamic way of life and by its many inscriptions reports the words of the Prophet.

In the early days, mosques like other type of buildings were built with a wide variety of materials, including mud, brick, timber and stone, depending on the local materials available. They were constructed according to local factors, such as climate and local cultures. And in their architecture features from existing buildings associated with Zoroastrian religious belief were borrowed.

3.2.1 Persian mosques: their architects and patrons

"The absence of authorship of the design of the mosque was a general rule which with some few exceptions was maintained until the end of eighteenth century and mostly the mosques were linked to the name of the patrons rather than that of the architect" (Frishman & Khan, 1994).

Therefore, the names of the architects of the mosques are unknown or can not be verify certainly in the majority of cases. On the other hand, the time scale adopted for some of these buildings was inadequate for them to be completed successfully during the life of its first architect (Hillenbrand, 2009).

In addition to the influence of architects, the patrons also played an important role in the development of architecture in Persia too. Their great buildings were personal monuments, demonstrations of power, personality, rivalries, taste and status. And because of their power and money, their names are more likely to be mentioned in the historic documents than the name of the architects.

3.2.2 The component parts of the mosque

The mosque, as a house of worship, has a standardized assembly of component parts, subject to some variations depending on whether or not a particular mosque is a congregational mosque or district mosque. There are two types of mosques: the local mosque which is smaller; and the main mosque or congregational mosque where the Friday prayer is recited. In both of these types, women remain segregated from male

worshipers, either by screens or by occupying a separate part of the building. The basic elements of mosques are described in paragraph 3.2.2.1and 3.2.2.2.
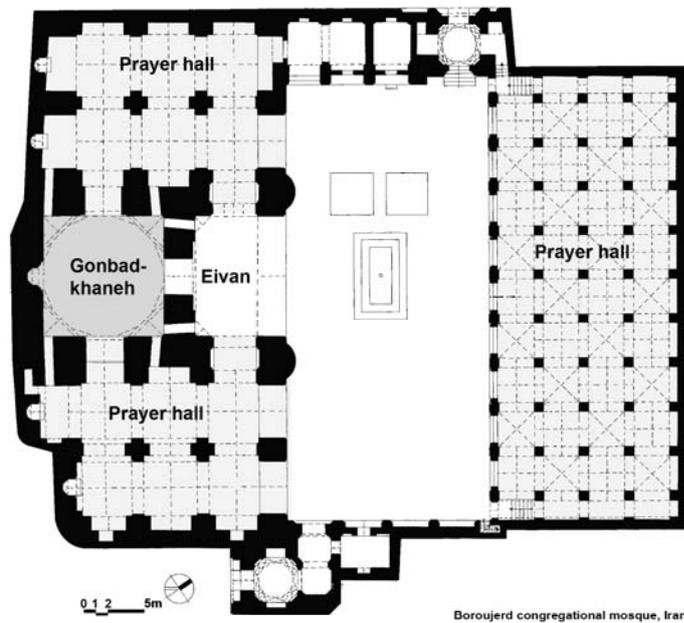
Figure 3- 2: different spaces in the plan of Boroujerd congregational mosque, Iran

3.2.2.1 Prayer hall

Prayer is the central part of Islam, and a Muslim prays five times each day directly to God without any mediator. It is both a physical and a spiritual practice and all five of the formal daily prayers follow the same basic pattern. Therefore, the prayer hall is the most important part of the mosque.

The prayer hall is a demarcated space, which is partly roofed and partly open, to provide accommodation for the congregation at prayer (Figure 3- 2). The number of worshipers and the climate are the most important factors in its design. According to Haji-Qassemi (1996), the prayer hall may be of the hypostyle type, having a roof

supported by a large number of evenly distributed columns. Hypostyle mosques are the earliest type of mosques with a square or rectangular plan with a courtyard and a covered prayer hall.

Alternatively, the hall may be covered by a single large dome or by a roof punctuated by one or more small domes.

All the mosques have a wall in their prayer halls which faces Mecca, in todays Saudi Arabia. This direction is called Qebleh and all prayers are directed towards it. The prayer hall has very simple furniture without chairs as the prayer is cited in lines and in the ground, therefore mostly is covered with carpet.

Gonbad-khaneh:

The Gonbad-khaneh is the large area under a dome in Persian mosques and shrines (Figure 3- 2) and in central Persia such as Kerman, Yazd, and Kashan, even the traditional houses have domes. However, in the mosque designs, this space is a part of prayer hall.

The use of dome in the harsh, hot, dry climate of Iran which works with sun, shade and wind produces a passive cooling and heating system in the Persian mosque design.

Shabestan:

The Shabestan is a hypostyle prayer hall (shown in Figure 3- 2) in Persian mosque or in Persian palace which is covered with circular roof. But it has different uses; while it is used as a prayer hall in mosques, it is an inner hall of the Persian palace.

In the mosque, it is used for prayering during the cold seasons, while in the summer if the weather allows, the courtyard is used for this purpose.

Eivan or Ivan:

The eivan (Figure 3- 2) is the most recognisable characteristic of Persian architecture from 2nd century B.C. Thus it is a pre-Islamic element of Persian architecure which was a well established form prior to the conquest of Iran in the mid-seventh century (Frishman, 1994).

It is a rectangular, vaulted hall with one end open where it faces a courtyard. In other words, eivan is a roofed or vaulted semi-open hall usually closed on three sides and open on the fourth which faces on to the courtyard of a building.
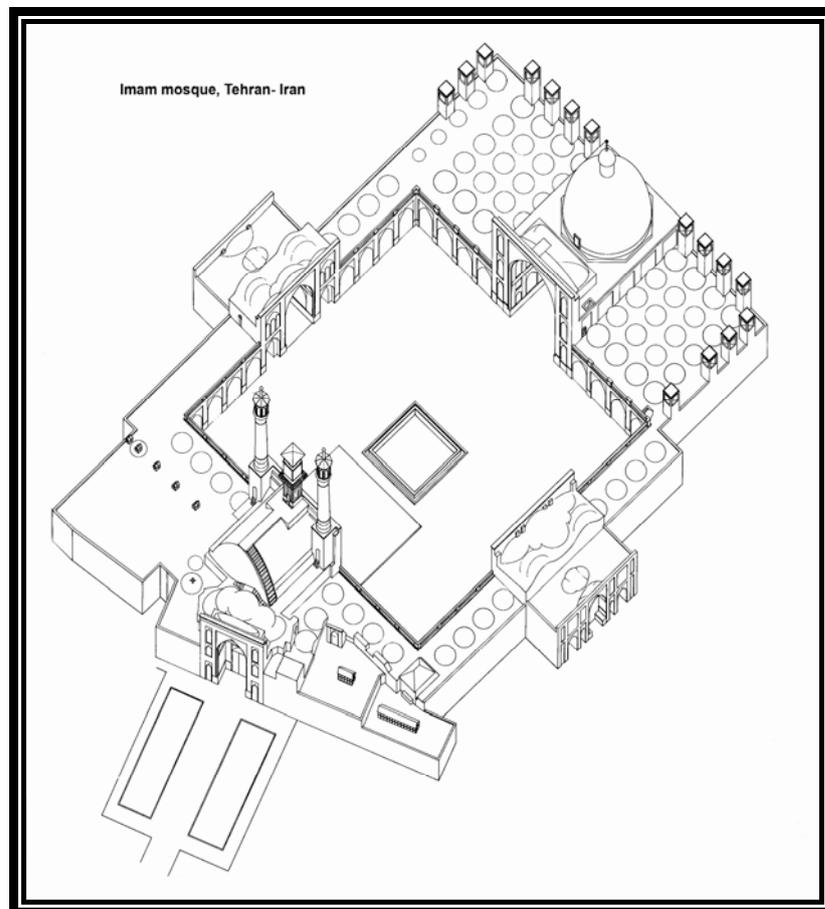
Figure 3- 3: An example of four-eivan in the perspective of Imam Mosque, Tehran (Haji-Qassemi, 1998)

Later, it was adopted in the design of Persian mosques and became one of the characteristic of it. It demonstrates the space between the courtyard and the prayer

hall. The four-eivan court (Figure 3- 3) was anticipated in Parthian times, but became a thoroughly established and dominant form in houses and mosque designs before the tenth century (Pope, 1965). However, the study of the eighteen case studies later in chapter five does not support this theory.

From symbolic point of view, the eivan separates the earth from the sky through its roof and defines the space through its sides and illustrates the place of man on earth in the God's house, mosque.

Minaret:

The minaret is a tower, usually attached to the prayer hall, from which the Muslims are summoned to prayer. The call to prayer is issued three times each day and the original purpose of the minaret was to ensure that the voice could be heard at a maximum distance.

According to Frishman (1994), the origin of minaret could be based on Zoroastrian symbolic fire-towers. However, Kleiss (2009) believes that its development in Syria was probably influenced by Christian church towers.

In Central Asia and Persia, the minaret was a distinctive architectural feature of mosques and became a compulsory element attached to the mosque with the form of a round tower or sometimes with a polygonal base, and as a rule, minarets are closely connected with the mosque in an extent that no longer recognizable (O'Kane, 1994). They are fifty or more meters high with spiral staircases and often serve as visual focal points and local landmarks. From the 17th century, two blue tiled minarets became a common characteristic of Persian mosque design (Frishman, 1994).

3.2.2.2 Sahn or Courtyard

The courtyard, (shown in Figure 3- 4) especially in a mosque or caravansary, is called sahn. The mosque's courtyard is most of the time surrounded by walls and is located in the middle of the building. Architecturally, the mosques may have wholly

interior court, in order to excluding the outer world and emphasising their inner circulation.
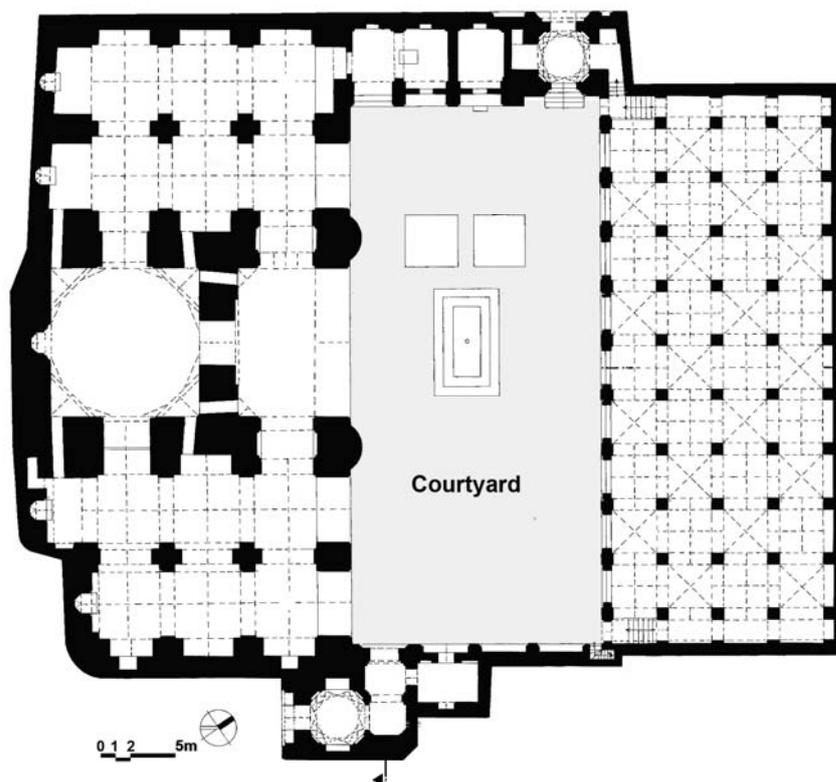
Figure 3- 4: Courtyard and pools in the plan of Boroujerd congregational mosque, Iran

The courtyard was a common element in the architecture of Persia due to the harsh, hot, dry climate. However, in the traditional Persian houses the courtyard has garden, while in the mosque design a pool has replaced it in the centre.

The courtyards in mosques are always characterised by repetitive elements in the facades that give them coherence and at the same time define their aesthetic purpose of showing unity.

Pool:

This feature, which is located in the middle of the courtyard (Figure 3- 4), may be with or without a fountain and may be intended for prescribed ritual ablutions before prayers, but is sometimes purely decorative as water is an important factor in Persian architecture. Removing one's shoes before entering a mosque and performing ritual ablutions before prayers are acts of self-purification and compulsory.

3.2.3   Categorisation of Persian mosques

No classification system for Persian mosques exists. The only existing category for Persian mosques is based on their size and importance: (1) the local mosque which is smaller; and (2) the main mosque or congregational mosque (or Jame) where the Friday prayer is recited.

Traditionally, the both of these mosques have very important roles in the Islamic counties and their use, visibility and history make them more accessible than any other types of building.

Throughout the history of Persian architecture, congregational mosques have been the most important type of building. The possession of a congregational mosque was a defining factor for any city. In other words, the existence of a congregational mosque in a city was a sign of its urbanity and each city has one congregational mosque that represents the best architecture of that area.

At the beginning, the congregational mosque was the focal point of a complex building associated with it which served as religious schools, shelters for travellers, court of justice, or even hospital. However later all these independent functions were accommodated in separate buildings and only two specific activities other than

worship found their place in the congregational mosque itself, religious teaching and Friday midday prayers, which combined religious, social and political elements of Islam together.

3.2.4   Persian mosques: architecture

The architecture of Persia across these centuries shows great variety, both structural and aesthetic, developing gradually and coherently. Without sudden innovations, and despite the repeated invasions and cultural shocks, it has achieved a distinct form different from other Muslim countries.

Frishman and Khan (1994) have recognised three stages in the design evolution of Persian mosque architecture: (1) in early formative stage, the earliest mosque form was very simple, similar to the first mosque in Islam, the Quba mosque in Madinah – Saudi Arabia. It has only a hall with an open courtyard surrounded by walls with a rectangular plan. (2) In the second stage, the plan became more complicated with more spaces and more complicated forms. They are not only rectangular, but follow the restrictions of the site. Moreover, the plans possess more spaces than just prayer hall and courtyard. Therefore, these mosques are more complicated than the first stage. (3) The third stage is characterised by the use of monumental scale, as we first see it in the Timurids era (from 14th to 16th century) but mostly later in the sixteenth century. Despite all these stages, the layout of most existing Persian congregational mosques, or Jame mosques, consist of an eivan with vaulted hall placed on each side of a bi-axially divided central rectangular courtyard as shown in Figure 3- 5 (Frishman & Khan, 1994).

Through the history of Persian architecture, some certain design elements of mosque design have persisted. The most striking were a marked feeling for scale and an impressive use of simple and massive forms in architecture, and a rather amazing consistency of decorative preferences.
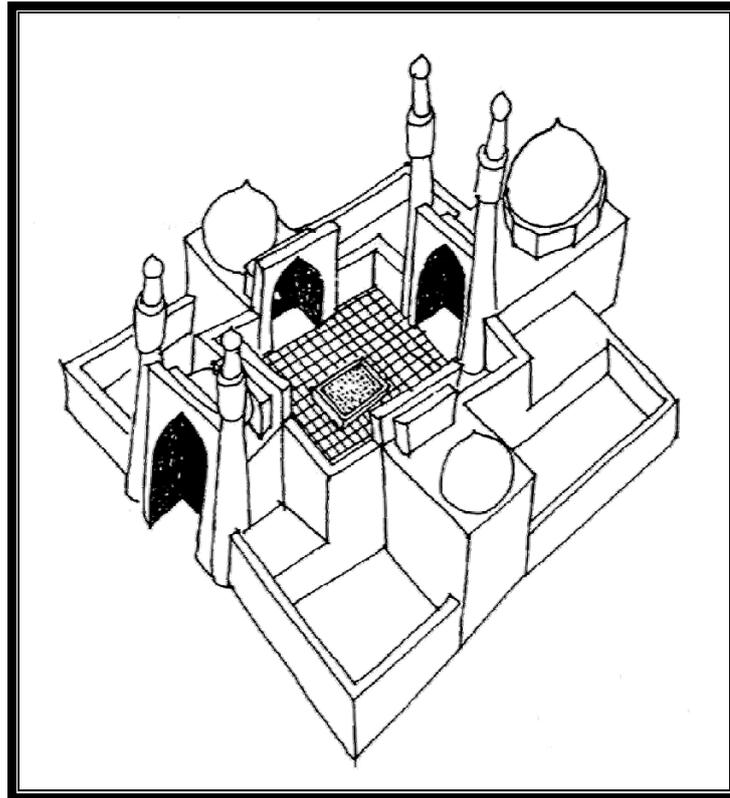
Figure 3- 5: A sketch of Persian Mosque style, the bi-axial four-eivan type
(Frishman, 1994, p. 13)

In this architecture, plan and layouts were of the highest importance. The notion of earthly towers reaching up toward the sky to fuse with the divine towers of heaven lasted through the nineteenth century, while the interior court and pool, the angled entrance and decoration are ancient but still common features (Pope, 1965). In its plan, the eivan is another recognisable characteristic of this architecture from 2nd century B.C. The four-eivan court, anticipated in Parthian times, became a thoroughly established and dominant form even before the tenth century (Frishman, 1994).

Mosques were places of beauty. "The mosques are the gardens of paradise and so the Persian architects made them, ornaments and valid expressions of Islam (Pope, 1965, p. 267)".

Islam has made a unique contribution to the architecture of mosques by geometry and calligraphy (Frishman & Khan, 1994). As Quran is held by Muslims to represent the word of God, calligraphy has a special place in the mosques. Even though both of them played major roles in the decoration of mosques, this research focuses on the layout of mosques.

3.2.5   Persian mosques: typology and development

As was mentioned, mosques are the most important building type in Islamic countries; especially the congregational (jame or Friday) mosques. Islam and therefore mosques focus on the Quran as the sole and essential foundation. However, after Islam came to Iran, no source existed that could suggest an architectural form for the mosque and anything that became accepted forms were developed through time.

The first design ideas were borrowed and adapted from existing religious buildings, such as Zoroastrian fire temples in Persia (Figure 3- 6) or churches in Syria, which provided the basis for designs. However, mosques were still different as there is no component part or object such as the cross in Christianity in a mosque.

In general, there is no direct relationship between the architectural form and the function in the mosque design (Frishman, 1994). The plan is simple and the only central idea in it is communication with the God. Mosque belongs to all Muslims on an equal basis and is open all times. Theological matter has a powerful influence in its architecture throughout history.

Figure 3- 6: An example of ancient fire temple in Baku, Azerbaijan (Lankenau R., 2004)

Just like any other architectural work, a mosque has a function and an artistic dimension. For example, not only must the prayer hall be suitable for its purpose in accordance with the rules of Islam, but also must the building to speak to the locals and provide spiritual identity for the community.

In the mosque design, rules of geometry were applied in a flexible manner and were used to provide general guidelines rather than lay down specific rule; therefore in this research, the Persian mosque shape grammar will try to produce a prototype rather than a complete plan. On the other hand, the exact role assigned to geometry in the

architectural traditions of the Islamic world is difficult to assess. A mosque should accommodate large numbers of worshippers arranged in rows, so it often follows rectangular outlines. However, mosque plans in urban centres might be dictated by the irregular boundaries of their sites too.

From the earliest times the congregational mosques have always been not only religious and social centre for the communities and the cities, but also a place for communal Friday prayer.

The mosque design reflects the specificities of the region. For example, the eivan used to be the most recognisable characteristic of Persian architecture before Islam, but later it became an important factor in the Persian mosque plans. In other words, each region of the Islamic world rapidly evolved a stylistic image of its own, rather than following the sectarian divisions within Islam beyond the borders of the Islamic countries (Frishman & Khan, 1994).

3.2.6   *Persian mosques: structural elements*

Two important structural elements of Persian architecture, vaulted and domed constructions, both existed even before the arrival of Islam in Persia.

In building construction, vault is an arched structure, usually forming a ceiling or roof. Vaults have always been a popular structural member in the architecture of Persian Mosques and had a very complicated history. Already present from Parthian dynasty, the eivan was also the most conspicuous element of Sasanian and later Iranian architecture, and with the vaulted eivan the visible shape of the vault became the dominant feature of the façade in Sasanian period and later (Pope, 1965). It is indeed a Persian characteristic to treat all structural functions decoratively if they are visible.

There are three major types of vaults (Figure 3- 7) and all are derived from a single elemental component: the arch. When an arch is prolonged in depth, a barrel or

tunnel vault is created. And a transverse vault is called when two tunnel vaults intersect each other and the diagonal vault is formed. If the arch is rotated on itself to form a hemispherical vault, it is a dome. In a more complex form, a dome can become a vault over a square plan and is capable of innumerable variations.
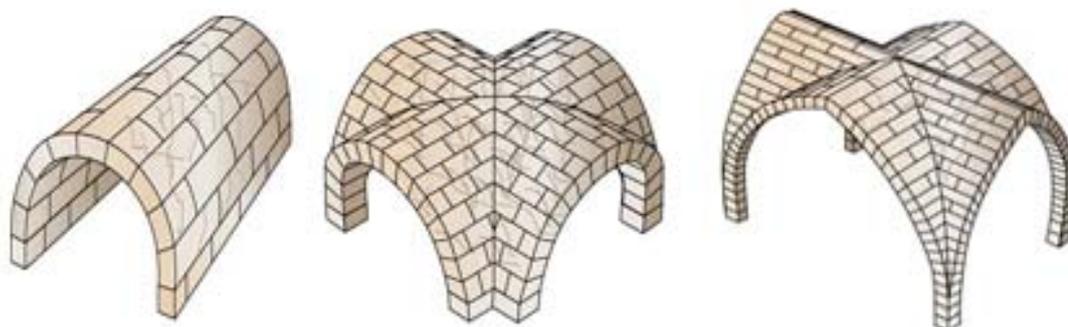
Figure 3- 7: Evolution of vaults from single barrel vault to more complex forms

Nayriz Mosque is the earliest of the single barrel-vaulted eivan-mosques still survives, repaired and added to. The most impressive of all, however, was the Ali Shah Mosque built at Tabriz with the conscious intention of surpassing all other such structures (Pope, 1965).

The creation of the dome above a square hall may be regarded as the most significant Sasanian contribution to Middle-Eastern architecture (Pope, 1965). Later, the dome became one of the characteristic of Persian mosques. However, onion shaped domes were uncommon until 18th and 19th centuries and they occasionally appeared on city mosques, such as Chiragh Mosque in Shiraz or Imam Reza shrine in Mashhad.

The double shell dome was used in the 14th century. "Two shells do not constitute a double dome unless there is a space between large enough for the entry of a man (Pope, 1965, p. 262)."

These two structural elements vault and dome, whether structural or decorative, still existed in Persian architecture and Persian mosque designs.

3.2.7 Persian mosques: material

As was discussed, Islam's early expansion was quite different from the slow spread of Christianity; but Islam, by contrast, quickly spread westwards. In the areas into which it expanded local populations used a wide variety of building materials, including mud, brick, timber and stone, depending on the raw materials available locally. Persia, like other regions of Muslim countries, had its own traditional, skills and building construction methods, and these local factors combined with climate, gave rise to a unique architecture in Persia which was influenced by existing local culture (Frishman, 1994).

The natural resources available for building vary considerably across the country. Wooden construction is found in limited areas, principally near the Caspian Sea and in some mountain villages. And stone constructions are rare too. Heavy clays, which are readily available at various places, encouraged the development of primitive building techniques. Blocks were compressed as solidly as possible and allowed to dry to form bricks. This technique, used in Iran from ancient times, has never been completely abandoned (Pope, 1965). The abundance of heavy clays in conjunction with a strong lime mortar also facilitated the development of brick construction. Both stone and wood were sometimes used too, but rubble masonry as well as brick construction were more widely used.

Brick was an accepted building material throughout the whole ancient Middle East and has been invented in Persia by the third millennium B.C. (Pope, 1965); it provided a durable building material and were utilised in various important structural forms. There were good reasons for preferring brick in Persia; it is more durable than stone, less expensive, and permits rapid construction. However, the potential beauties of brick, such as various types of bonding, ornamental end-plugs, contrasting textures, pattern inlays and overlays, began to be thoughtfully realised only in the tenth century.

However, Persian architecture has continuity and nonetheless a unique style regardless of the choice of material in it (O'Kane, 1994). This unity can be seen even though detail was varied as material changed. The combination of strength and simplicity of forms in this architecture create the unique style of Perisan mosques.

3.2.8   Persian mosques: climate

Iran has mostly arid or semiarid climate with cold winters and hot summers; however alongside Caspian coast and Persian Gulf the climate is subtropical and the northwestern mountainous regions experience colder winters with occasionally heavy snows that melt in early spring.

The study of the Persian architecture reveals the important role of the climate in the design of buildings in Iran. In subtropical regions, the natural ventilation is a very important factor in the design of the buildings and has been maintained with open, long and narrow plans. While in the northwestern region, with cold winters, the sunshine is very important and the buildings are located in a way to receive the maximum amount of sunshine and to reduce the effect of cold winds in the cold season. In the regions with arid and semiarid climate which include majority of Iran, the focus of design is on the reducion of the heat during the day, while the natural ventilation because of the dry weather does not play an important role.

However, these differences can not be distinguished in the design of Persian mosques in these areas, as the dome is a popolar element in the design of Persian mosques in all of these climates. Besides, all of the Persian mosques do not have windows to control ventilation except towards courtyards.

As was mentioned, the only influence of the climate in the mosques is mostly limited to the way spaces are used in the different seasons of the year; for example, courtyards are used for praying instead of prayer halls during the summer time in the arid and the semi-arid climate, while this is not the case for the subtropical region in the south of Caspian Sea.

3.2.9   Persian mosques: Shia

Prior to the spread of Islam in Iran, Zoroastrianism dominated Persian Empire and it was not until the 9th century that majority of Iranian became Muslim.

The most important sectarian division in the Islam is the one which separates Sunni and Shia believers. In the great schism of Islam, one group among the community of believers maintained that leadership of the community following the death of Prophet Mohammad rightfully belonged to Mohammad's son-in-law, Ali, and to his descendants. This group came to be known as the Shiat Ali, the partisans of Ali, or the Shias (The World Factbook, 2009).

During the Savafids (from 16th to 18th century), Shia became the state religious in Iran. However, the largest concentration of Shias in the first century of Islam was in southern Iraq and it was not until the Safavids (16th to 18th century) that the majority of Iranians became Shias and it became the state religion. But, these sectarian divisions within Islam did not affect architectural appearance or style of mosque design (Frishman & Khan, 1994).

Today, ninety eight percent of Iranians are Muslim, and among them eighty nine percent are Shia and only nine percent are Sunni, mainly in the south and southeast of the country (The World Factbook, 2009). However as was mentioned, these two major branches of Islam have some small religious disagreements and their difference over the rightful successor to Prophet Muhammad. Plus, majority of the population of Iran are Shias; therefore, the influence of different brances of Islam in the mosque designs can not be recognised within the borders of Iran. Finally, Frishman and Khan (1994) confirm that these sectarian divisions within Islam did not affect the architectural appearance or style of the mosques in the Islamic countries either.

3.3   *History of Persian Architecture in the Islamic Period*

In this section, a brief history of Persian architecture after Islam until the arrival of modern architecture will be discussed. This period begins with the conquest of Persia by Muslim Arabs and the introduction of Islam to Persia, the gradual conversion of people to this new faith, and 200 years of Arab ruling. Then is the rise of local dynasties which did not have big influence in the Persian architecture and will not be discussed here, such as the Taherids, the Saffarids, the Samanids, the Ghaznavids, the Ziyarids, and the Buyids.

Later, the Saljuqids formed an empire in nearly all the Persian borders before Islam and ruled it from the 11th to the 12th century. The invasion of the Turkish Saljuqids and the powerful state that they formed is followed by the Mogul invasion. After this invasion, the Timurids dynasty (from 14th to the 16th century), mainly in western Persia are discussed. The rise of the Safavids (from 16th to 18th century) and the significance of their unifying the country under their enforced Shiism come next. The rise of Qajars (from 1796 till 1925) follows and the formation of the Pahlavi dynasty (from 1925 to 1979) is treated next.

However, the modernizing efforts of Reza Shah Pahlavi in Iran and in Persian architecture and the reign of Mohammad Reza Shah, the revolution of 1979, and the formation of the Islamic Republic of Iran will not be focused upon here.

It should be mentioned here that the beginnings of an Islamic architecture in Iran are still almost impossible to identify properly. Remaining buildings are few, most of them are very uncertainly dated and literary information about them is insufficient or difficult to interpret. However, this brief will be based on the most reliable existing sources.
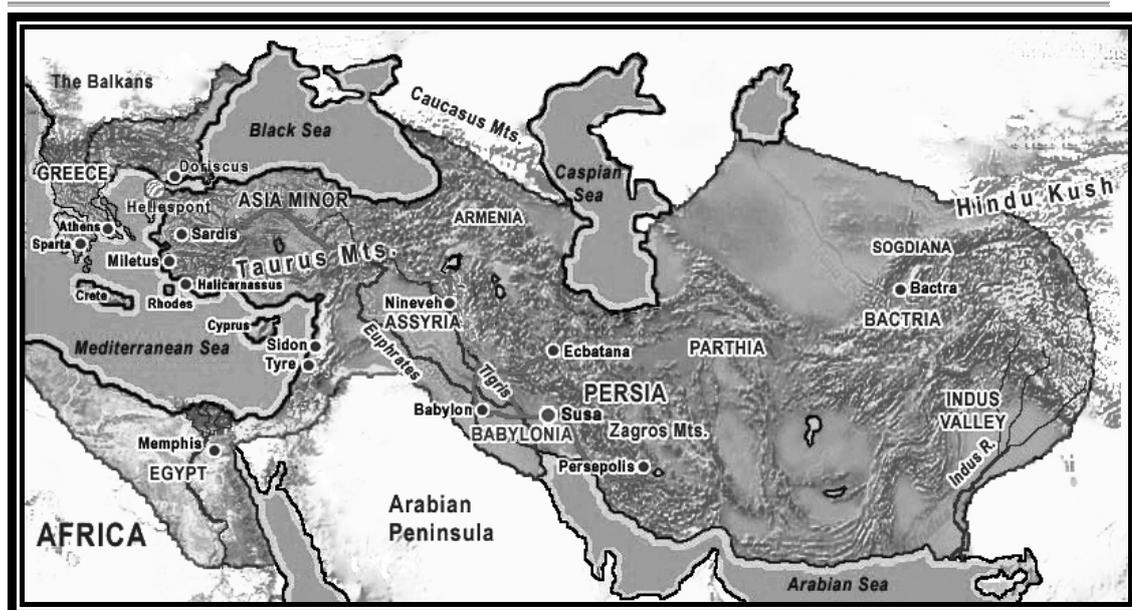
Figure 3- 8: The map of Persian Empire before invasion (The National Endowment for the Humanities, 2010)

3.3.1 Early Islam Architecture

Before the rise of the Sasanians in Iran, the Arabs were gradually spreading northward and westward, penetrating into Syria. In 637 AD, they occupied the Sasanian capital and in 641-42 AD, they defeated the Sasanian army at Nahavand and Persian provinces and cities came one by one under the authority of them (Yarshater, 2006).

With the collapse of the Sasanian dynasty and the Zoroastrian temples, the era of Persian Empire (Figure 3- 8) came to an end, and a new era begun and for two centuries, Persia was ruled by Arabs. However, the Persian daily life continued as usual, local government proceeded as usual, and the essential elements of Sasanian culture continued to operate within the new framework (Pope, 1965). And even these cutoms, laws and traditions were adopted in the east of Islamic empire (Yarshater, 2006).

During this period, conversion to Islam was gradual and it was only by the ninth century that because of the political and economic pressure, the majority of Iranians became Muslim (Yarshater, 2006). The final acceptance of Islam brought a much

needed peace and was accompanied by a prosperity that the furnished the economic basis for creative energies (Pope, 1965).

In the ninth century, the daily worship at fixed hours of the day and the communal prayers on Friday became routine for people, therefore new mosques were needed everywhere and at the same time, the organisation of the Islamic Empire which was dominating a culturally diverse area opened new avenues of communication, increasing trade, and creating an expanding economy and supplied the wealth needed for these constructions.

In the first part of this period, the conquering forces enforced no rules on the design of religious buildings and the existing buildings such as Zoroastrian fire temples (Figure 3- 6) and palaces were used for prayers (Yarshater, 2006). In the contrast to the palaces which showed the power of kings, the mosques belonged to all people and had a certain simplicity and dignity. Later when new buildings were built, they had borrowed features from existing buildings associated with local religions and cultures. This theory (Frishman, 1994) can explain the importance of the dome in the mosque design. The new buildings were created out of local material, techniques and styles. However, later these structural elements became lighter, more sensitive, more varied and more expressive than before.

Islam is concerned with the spiritual aspects of life, as well as all other spheres of life, including civic, economic, and judicial. Therefore, the early mosques had many functions too. They were used not only for worship, but also for the basic educational reasons. Later, they became political institutions of central influence with varied functions and sometimes they served as the courts of justice too.

Architecturally, the mosques were simple with dignity and were open to all people at all times. They were focused in the life and the meaning of the community and belonged to all Muslims on an equal basis. Mosques were spiritually coextensive with the whole life of Persians and were often physically integrated with the city and

merged with the surrounding buildings and their external walls, facades and their areas were difficult to define. In this period, they were even sometimes just an interior court, designed to exclude the outer world and emphasise their inner courtyard. These courts are characterised by repetitive elements in their façades that give them coherence and the deepest kind of unity.

These first mosques were extremely simple, compared with lavish Sasanian structures and had shabby and unimportant architecture (Pope, 1965). The majority of pre-Saljuqid mosques have hypostyle prayer halls (Figure 3- 9) and the Sasanian legacy is apparent in these mosques, as they have vaults instead of flat roofs and round piers (Frishman, 1994).
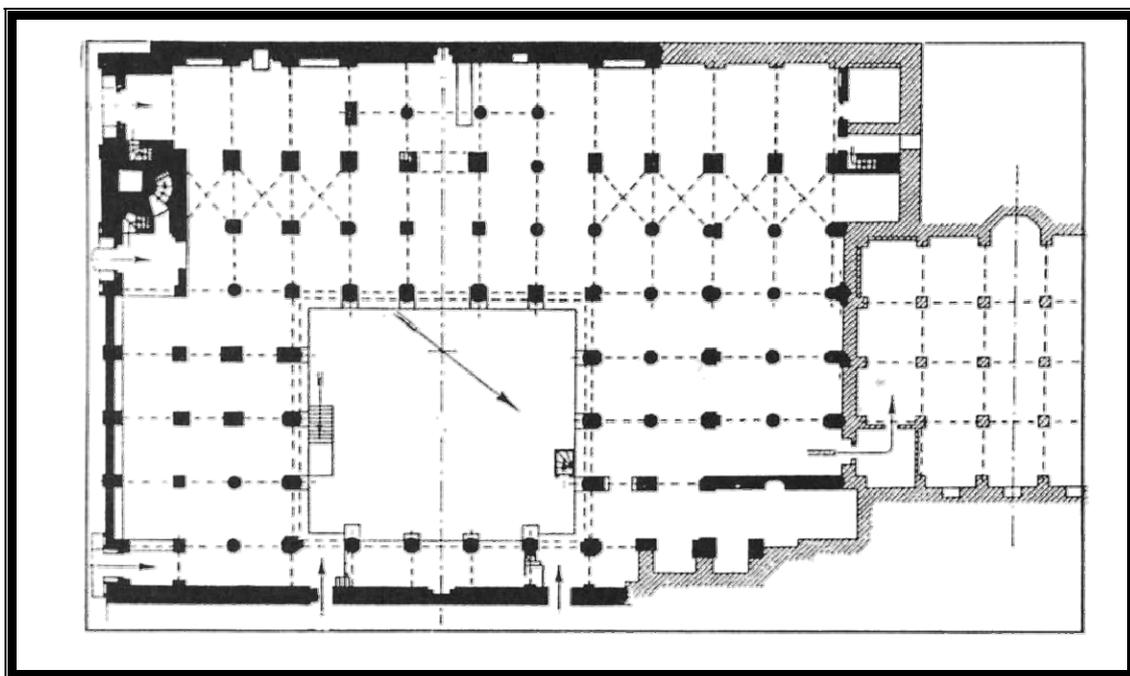
Figure 3- 9: An example of hypostyle prayer hall in the plan of Nayin mosque (p.18, Pope, 1965)

As was mentioned, the mosque designs in this period had been very simple and lacking decoration and the only existing decoration is the existence of structural elements such as columns and domes within the mosque.

Pope (1965) has identified three basic types of mosques in this period: (1) the pavilion, a dome over a square chamber which was very similar to the Zoroastrian fire temple in the Sasanian period before Islam (Figure 3- 6); (2) the open eivan toward Mecca with a simple barrel vault in the tradition of the Taq-e-Kasra, built before Islam too (Figure 3- 10); and (3) the open court, surrounded by arcades. Eventually, all three types were merged.
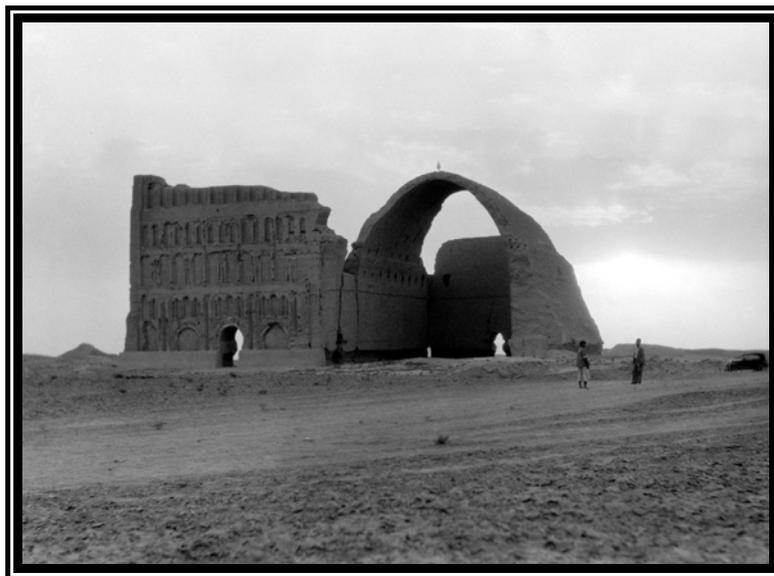
Figure 3- 10: Taq-e-Kasra, 1932 (Circle of Ancient Iranian Studies, 1998)

Within the first three centuries, many important mosques were built and Sasanian materials and building methods continued in use, even as late as the fourteenth century. In brief, the major elements of the classical Persian mosque in this period are the hypostyle hall, courtyard, dome and eivan and according to many scholars, these major elements were available for experimentation before Islam.

The first Persian dynasty after Islam was the Taherids which ruled Iran from 821 till 873, later the Samanids (819-1005) came to power. But their ruling came to an end around 977 by the Ghaznavids who lasted until 1186.

3.3.2   The Saljuqid Architecture

The Saljuqids were the first dynasty after Islam who formed an empire in nearly all the Sasanians' borders and ruled it from the 11th to the 12th century. This was the first time after two centuries that all of Persia and its dependencies came under a single and powerful dynasty (Yarshater, 2006). This stability was good for art and architecture.and many mosques with dome chambers and hypostyle plan were built.

In this period, Esfahan was the Persia's capital and its congregational (or jame) mosque can be considered one of the greatest mosques in Iran. This mosque (Figure 3- 11) is one of the best examples of Saljuqid architecture. Moreover, it shows another revolutionary development in the mosque design, which is the insertion of four-eivan facing the courtyard into the hypostyle plan (Frishman, 1994).

Ispahan. — Cour de la Grande Mosquée.
oldbookillustrations.com
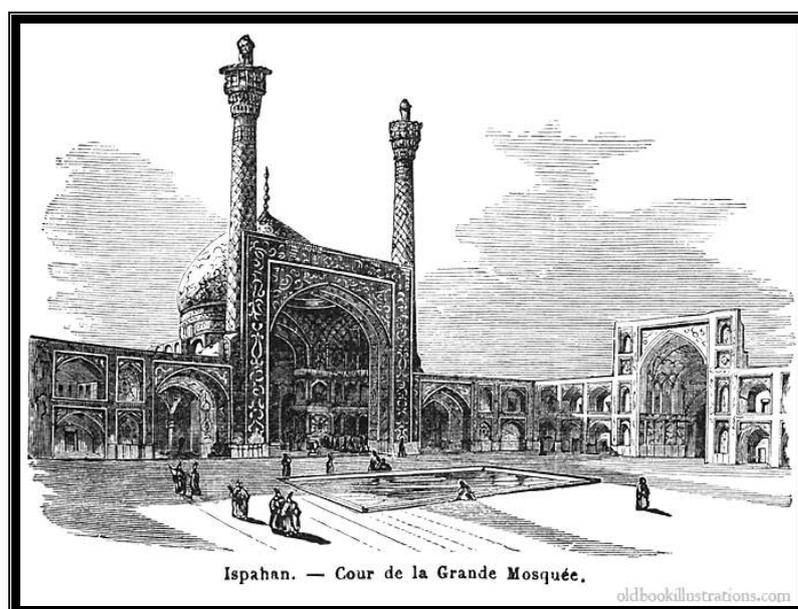
Figure 3- 11: Esfahan Jame Mosque (the Dictionnaire encyclopédique Trousset- Paris, 1886 – 1891)

However, this mosque is not purely Saljuqid and it has been completed and decorated in different periods. This building has a four-eivan court (shown in Figure 3- 12) which was not built at the same time, but it was all designed and constructed in this period. The change of the mosque's shabestan style into a four-eivan design is

considered the greatest development in the Persian architecture at the time (Haji-Qassemi ed., 2004b).
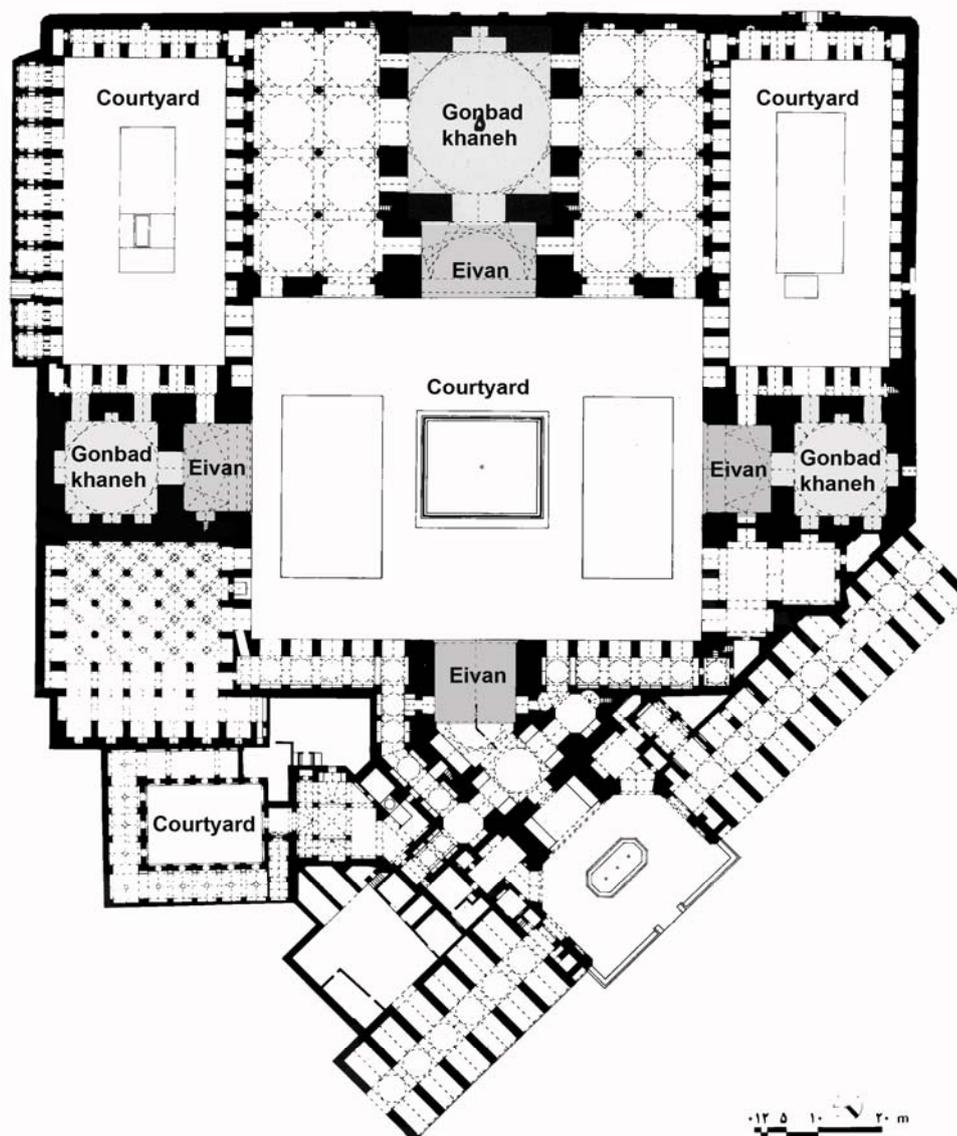
Figure 3- 12: The concept of four-eivan in the plan of Esfahan Jame Mosque (Haji-Qassemi ed., 1996, p. 24)
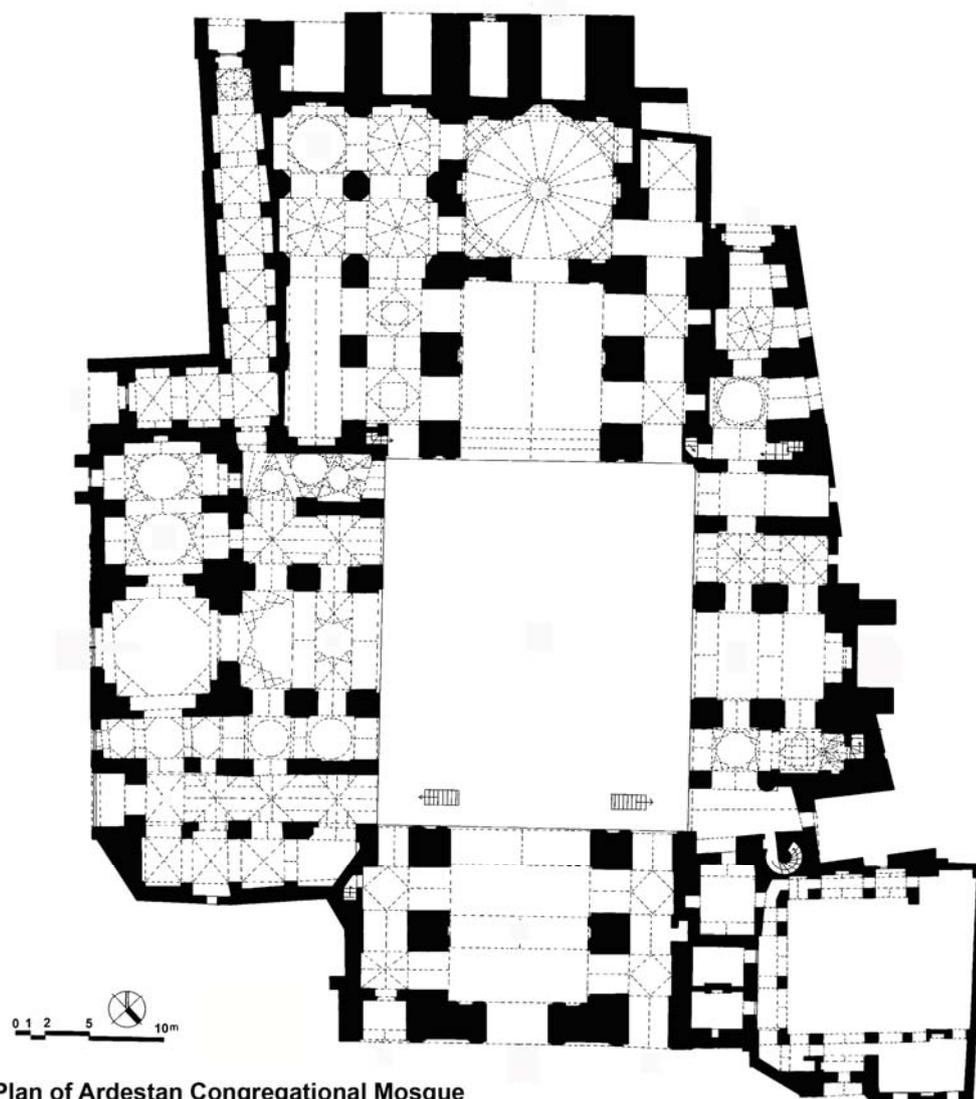
Plan of Ardestan Congregational Mosque

Figure 3- 13: The plan of Ardestan congregational mosque

Other important Saljuqid mosques are all built in the same style of Esfahan congregational mosque, such as the Ardestan congregational mosque (Figure 3- 13), the Zavareh congregational mosque (Figure 3- 14) and the Gulpayegan congregational mosques and the four eivan style remains the classic model for large mosque right up to modern times.

0 1 2   5 m
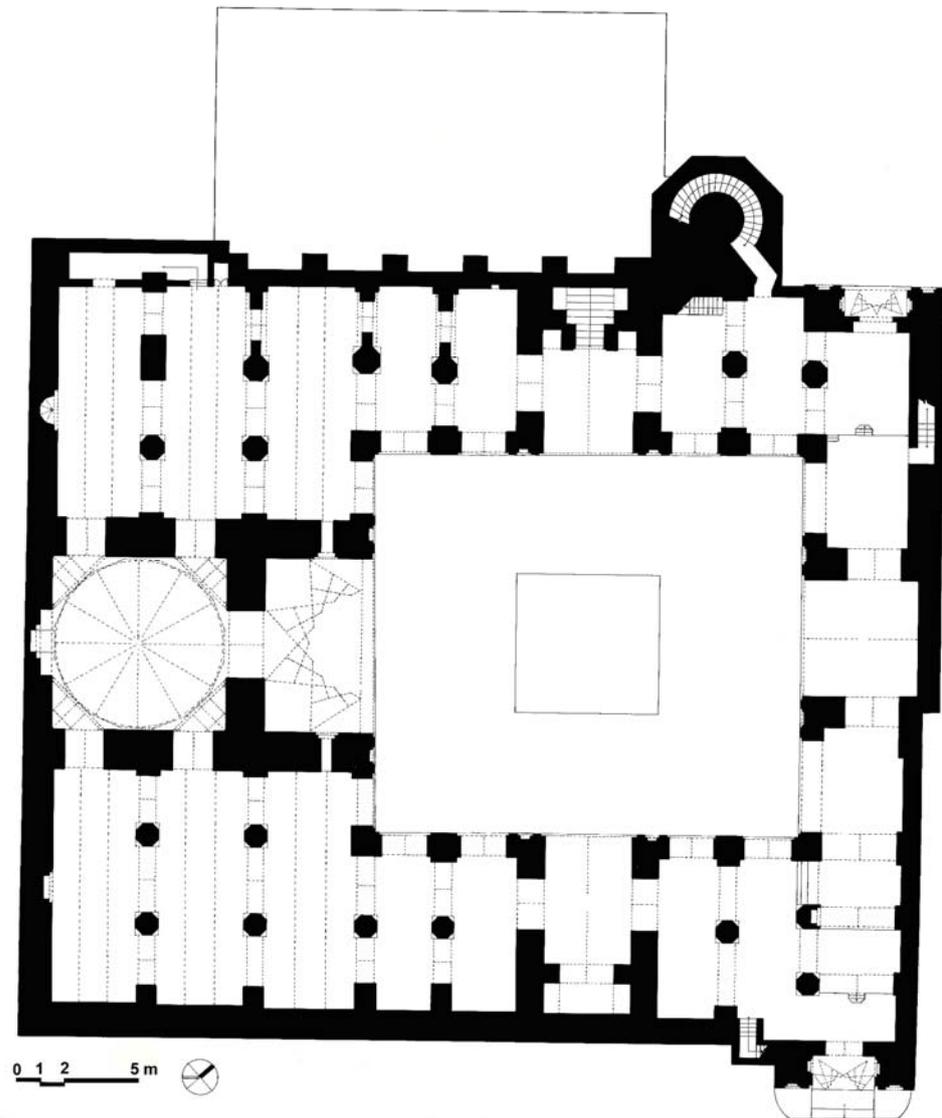
Figure 3- 14: The plan of Zavareh congregational mosque

According to O'Kane (1944), the most important decorative medium of Saljuqid mosques was their basic structural material, baked brick.

3.3.3   The Moguls Architecture

The Moguls invaded Persia around 1218 to 1220 and by 1230, all resistance against them was broken. Persian cities had never before suffered in such a scale from loss of human lives and demolition. This horrendous destruction left Persia in ruins from

which recovery was slow. In 1304, Ghazan Khan which was ruling the country converted to Islam, but the Moguls did not last long after that.

In the previous dynasty, baked bricks in the mosques were not covered and used as a decoration in the mosques, however, in this period tile mosaic gradually became the main, and in some cases the only, form of decoration on mosques, for example in the Yazd congregational mosque (Figure 3- 15).
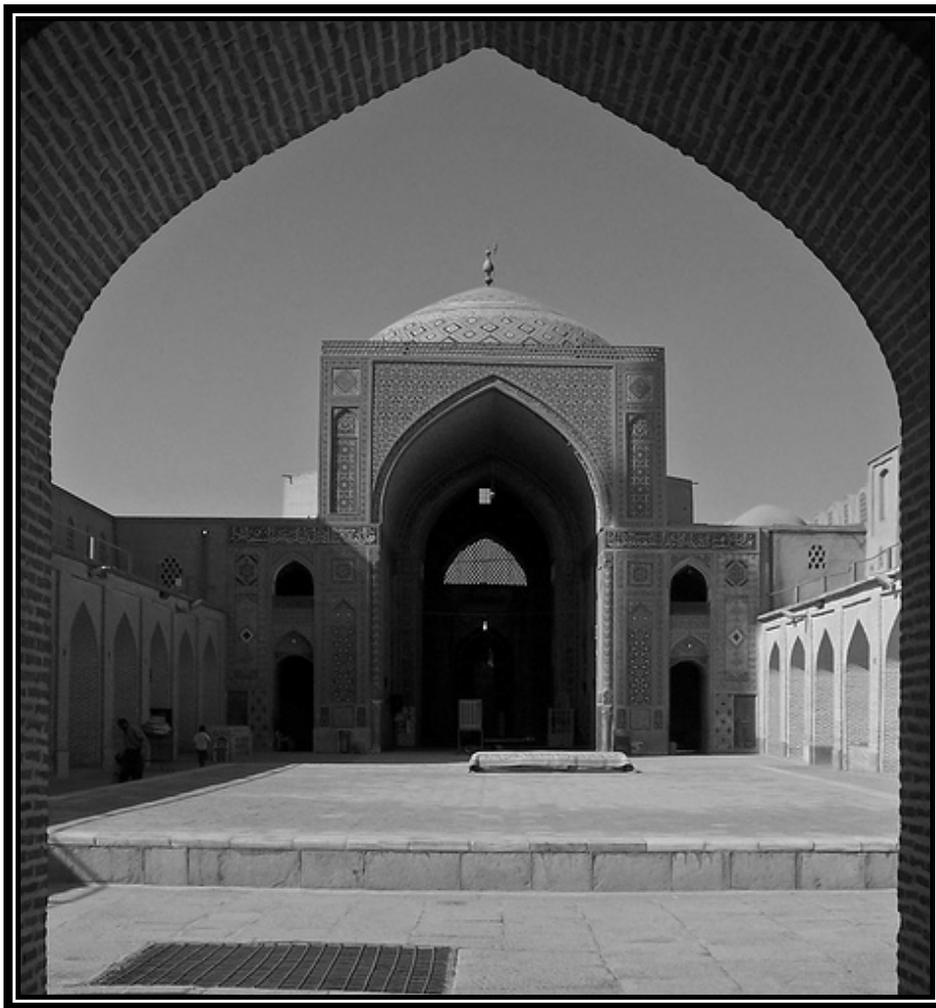
Figure 3- 15: the tile work in the facade of Yazd congregational mosque

3.3.4   *The Timurids Architecture*

The Timurids belonged to a clan of Moguls who ruled over Persia from the 14th to the 16th century. They developed many Saljuqids' traditions in architecture and all

the major mosques of this period feature the classical four eivan plan. Another important characteristic of this architecture was the axial symmetry, notably in the Gowhar Shad Mosque in Mashhad (Figure 3- 16).

Double domes were also used in this period, a technique which makes domes more conspicuous on the exterior, but which underlines the character of Timurids architecture as one which emphasizes display at the expense of structure (Frishman & Khan, 1994).

The Gowhar Shad Mosque (Figure 3- 16), which is now located near the shrine of the Imam Reza in Mashhad, can be considered as one of the most beautiful surviving monument of this period, as not only has a classical four-eivan plan, but also its entire façade is covered with the best quality mosaic and brick. (Pope, 1965).

Figure 3- 16: The Gowhar Shad Mosque, Mashhad (O'Kane, 1994, p. 132)

Another great monument of fifteenth century is Imam Mosque also in Mashhad.. And further north in Tabriz in the same period, the Blue Mosque (1465) was built. Its unusual plan with a completely covered roof was a necessity in the severe climate of

Tabriz. The quality of the tile work is outstanding and its ornamentation throughout is bold and dramatically varied.
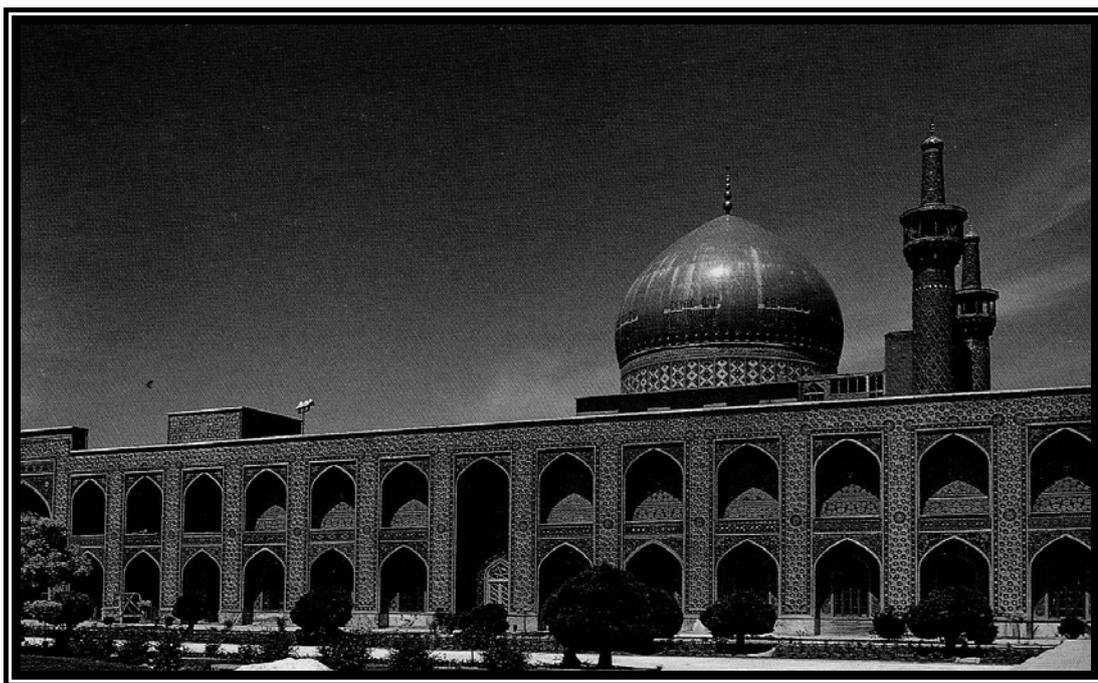
In brief, Timurid architecture is distinguished by its grand scale, bold engineering solutions, and magnificent decoration. And the use of brick and mosaic for the decoration porposes inside and outside of the mosques became a common feature in the design of the Persian mosque after this period.

3.3.5   The Safavids Architecture

The Safavids were in power from 16th to 18th century. They were important for two major reasons, first was the enforcement of the Shia branch of Islam in Persia and the other was the unification of the country under a single rule, which has continued as such till now (Yarshater, 2006). Shia Islam was a legacy of the Persians and has come to be identified closely with Iran and became then, as it is now, the state religion.

The arrival of the Safavid Empire created national pride, but Persia was suffering from wars which frustrated any capacity for grand architecture. On the other hand, the major towns already had enough mosques.

Later during Shah Abbas period (1589-1627), as the country was economically strong and politically stable, the rise of Persian architecture began. Although there is no great structural innovation from this period, the existing patterns and methods of architecture developed and this architecture represents the peak and final expression of Persian Islamic architecture.
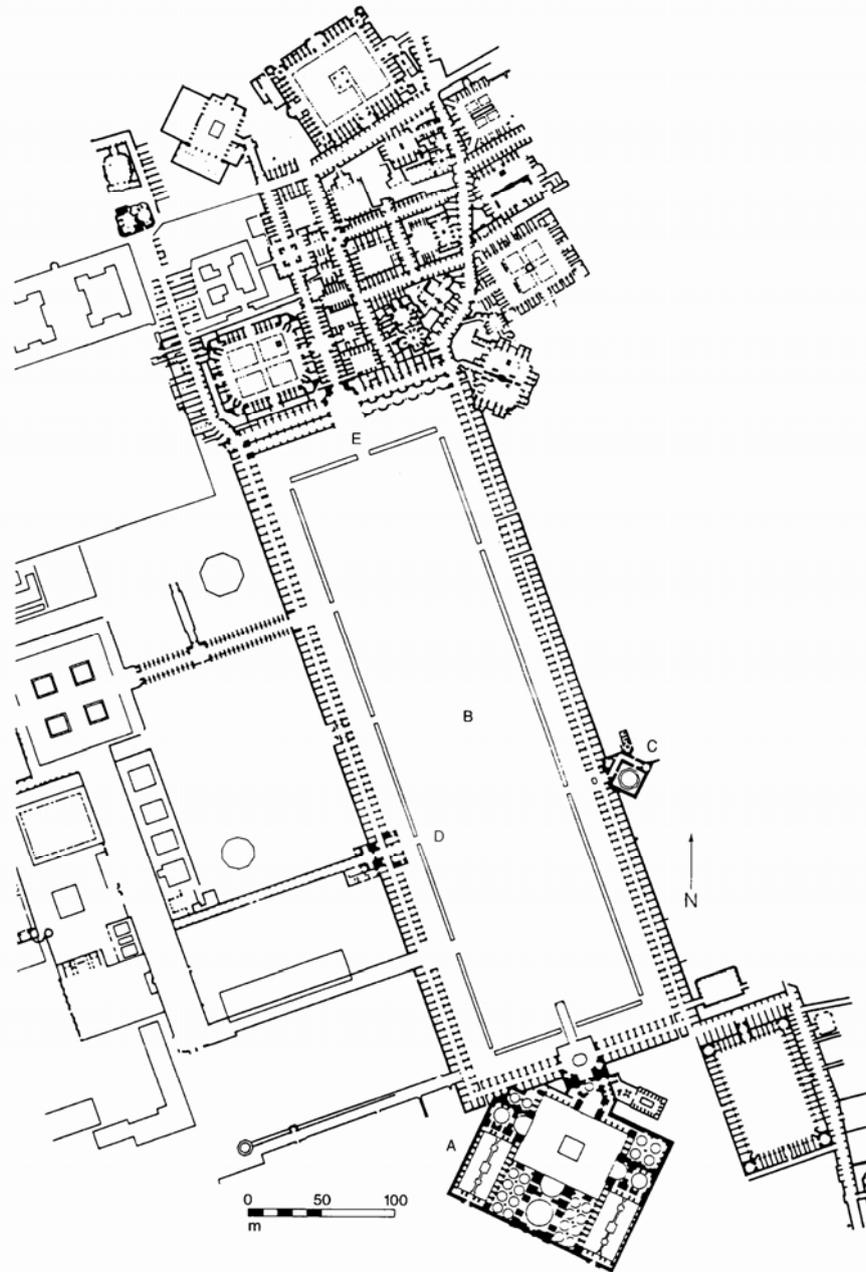
Figure 3- 17: Plan of Naghsh-e-Jahan square in Esfahan with Shaikh Lotf Allah mosque, plan C (O'Kane B., 1994, p. 137)

The establishment of distinctive public spaces is one of the most important urban features of this time, for example Naghsh-e-Jahan square (Figure 3- 17) and Chahar Bagh both in Esfahan. In this period, we can see the combination of monumental gateway, bazaar, school, garden plan and prayer hall in the new urban spaces.

Moreover, these new urban spaces, such as Naghshe-e-Jahan square, were based on the geometrical networks and Esfahan became an outstanding example of city planning which mosques are fully integrated within.

Moreover in this period, some important city walls, such as Tehran city wall, were built and the use of natural elements, such as water and plants, in the public spaces became common.

Esfahan became capital during Shah Abbas and was enlarged by a number of great monuments such as the Jame and the Sheikh Lotf Allah mosques and many new mosques, palaces, bridges, avenues, and parks were built.in it.
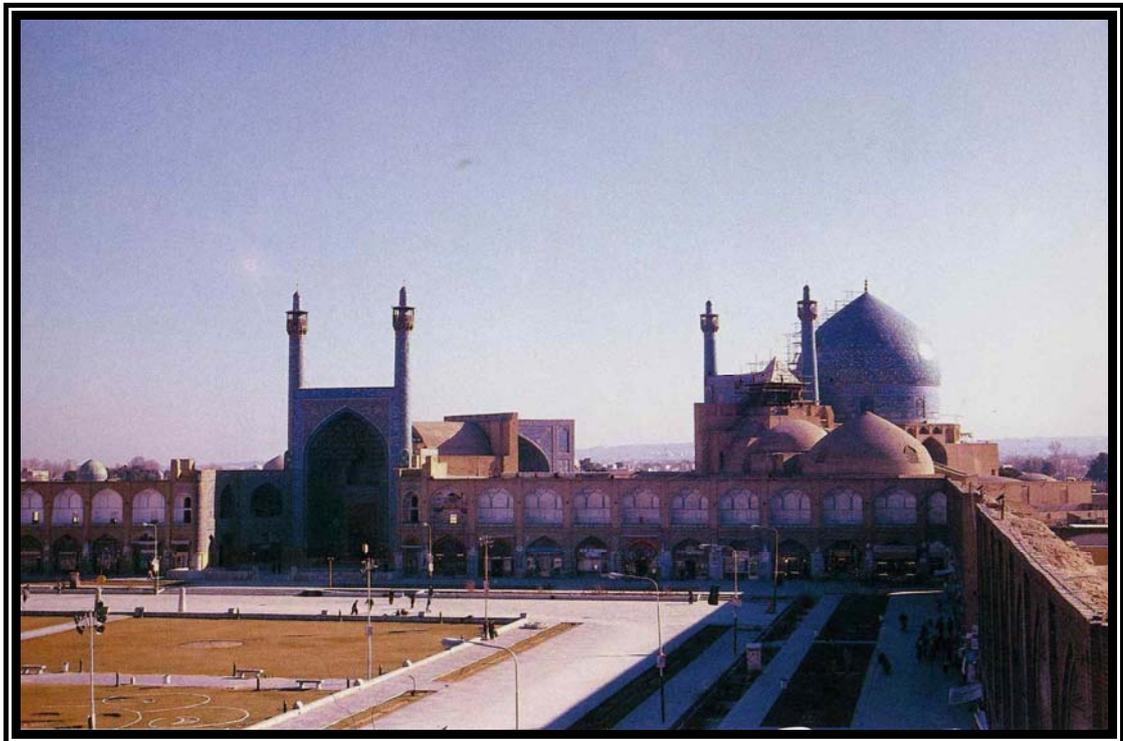

Figure 3- 18: The view of Esfahan congregational mosque from Naghsh-e-Jahan square (Haji-Qassemi ed., 1996, p. 30)

As was mentioned, Esfahan congregational mosque (1638), shown in Figure 3- 18, is among the masterpieces of Persian architecture (Pope, 1965). This mosque represents the best of a thousand years of mosque building in Persia. The formative traditions,

the religious ideals, usage and meaning, major structural elements, the ornamentation, and the plan which had slowly matures from a combining of earlier and simpler types are all fulfilled and unified in this mosque. The whole mosque is of impressive proportions with blue mosaic façade which dominates the square in front of it, even from a distance. By contrast, the royal palace also in the Naghshe-e-Jahan mosque has a humble and modest presence, which shows the overwhelming priority of religion over secular places in the city at the time.
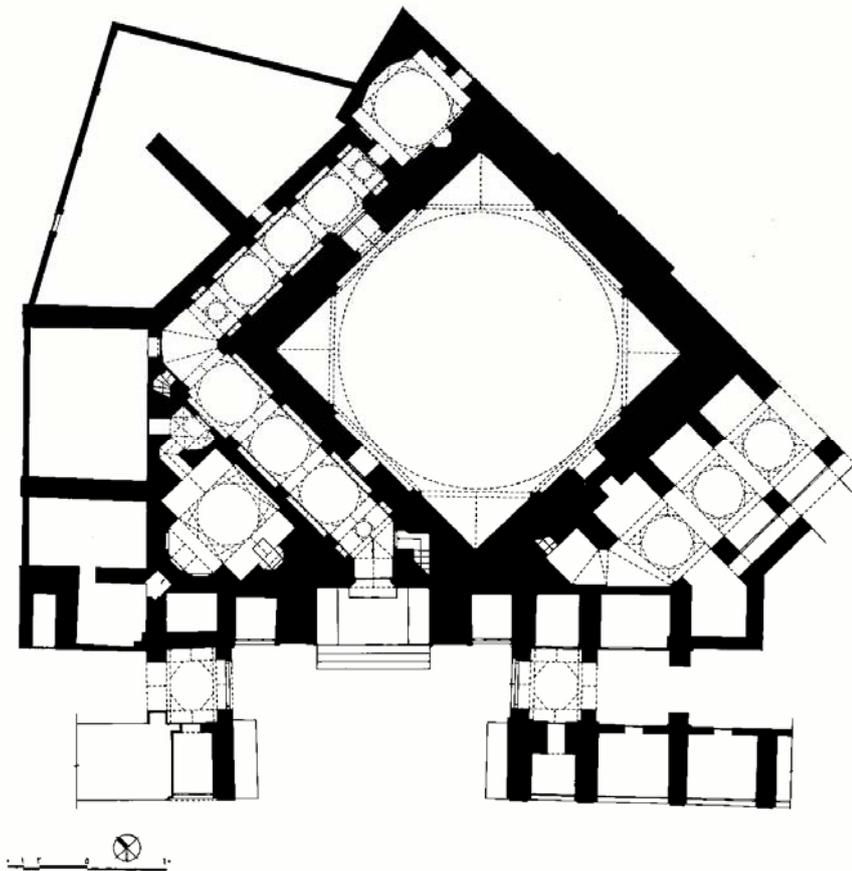
Plan of Shaik Lotf Allah Mosque, Esfahan

Figure 3- 19: Plan of Shaik Lotf Allah mosque in Esfahan (Haji-Qassemi, 1996, p. 128)

However, both the ground plan and the structure of this mosque are simple and there are no closed doors, no privileged positions and no hierarchy in it. This noble design which expresses the spirit of Islam has few rivals (Pope, 1965).

The Sheikh Lotf Allah Mosque (shown in Figure 3- 17, Figure 3- 19and Figure 3-20) which was also built in the seventh century (1603-18) is a simple and modest mosque. Its dome on a square chamber is similar to Sasanian architecture and the chamber itself marks the final perfection of the dome-on-square plan (Pope, 1965). In order to emphasize its powerful form, the chamber is entirely empty. Its scale is ample and the patterns are strong.

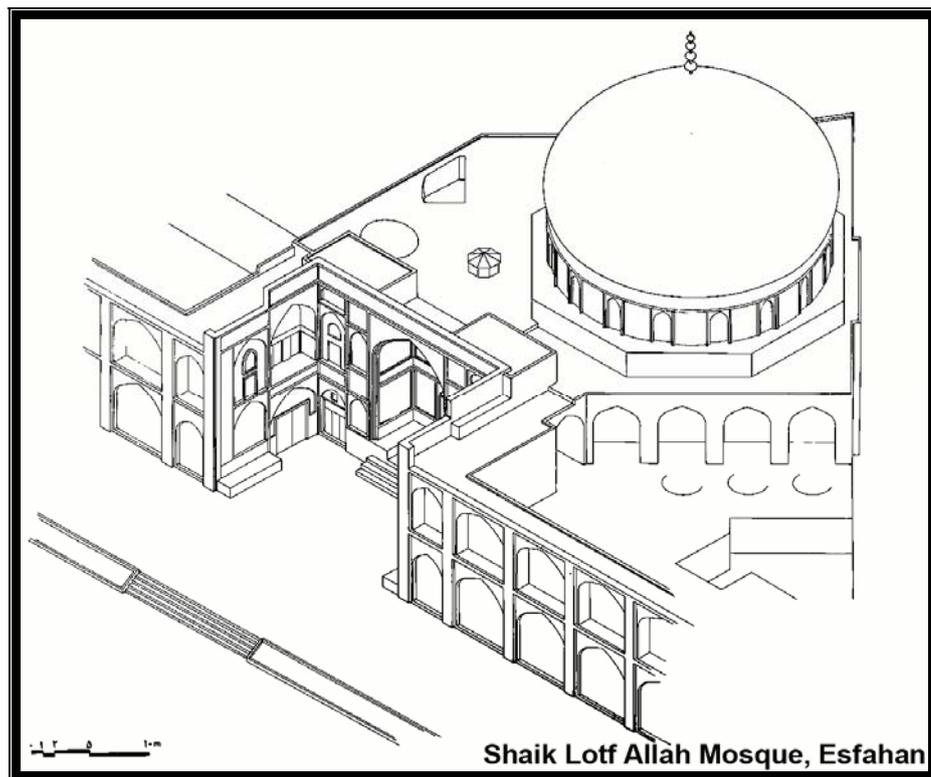**Figure 3- 20: Perspective of the Shaik Lotf Allah mosque in Esfahan (Haji-Qassemi ed., 1996, p. 126)**

After Shah Abbas, the signs of decline began to appear in the Safavid state and by 1722, Esfahan was besieged and the Safavid army were defeated.

In brief, the Safavid architecture was conservative and it seems that by the end of 17th century, the gradual development of Persian architecture came to its end.

3.3.6 The Qajars Architecture

The Qajars family ruled Persia from 1796 till 1925. Under the Qajar, the country saw no important building and the very few large buildings of this period are without distinction. The architecture of this period continued to be conservative, like Safavid and in the mosque design, the courtyard remains the focus of innovation and tile work stayed as the main decorative medium (Hillenbrand, 2009).

The first examples of the modern architecture in Persia were built during this period, as a result of the increasing communication with Europe. However, the Persian architecture was thoroughly modernised in the Pahlavi period.

3.3.7 The Pahlavi's Architecture

The Pahlavi dynasty ruled over Iran from 1925. In 1979, the ruling monarchy was overthrown and the last Shah was forced into exile and Iran became an Islamic republic. Iran was known as Persia only till 1935.

One of the features of architecture of this period was its desire to adopt aspects of Western architecture in such a way that Iran would become equal to the West. Therefore, Western architcts were invited to design new buildings in Iran. As a result, the traditional architecture came to an end in this period. This architecture wanted to inspire from the West in order to achieve new glories and this desire for modernisation and construction of new and monumental structure can be seen in the buildings of this period.

The twentieth century has not been a period of distinction for the design of Persian mosque. On the other hand, contemporary mosque designs are out of the scope of this research and this research includes the study of traditional Persian congregational mosque plans built before this period.

3.4   Case studies

The aim of this research is to study and to classify Persian mosques in a general degree which is expected from any classification system, but at the same time, to include sufficient details in order to distinguish between them. In order to do so, a group of eighteen Persian mosques (Figure 3- 21) will be analyised. A brief history of these mosques will follow.

Figure 3- 21: Distribution of case studies in the map of Iran

This study has been restricted to the analysis of the first floor plans of one-storey mosques not only because the underlying conventions were particularly easier to discover and explain; but more importantly, it was easier to lay the groundwork for

an analysis of common mosque types which allows for a more subtle analysis of types.

All of these congregational or jame mosques are within the current borders of Iran, from eighteen different cities. As often each city has only one jame, they represent the architecture of eighteen areas of Iran.

The exact construction dates and their architects, as will be discussed later, are mostly unknown. However, they cover a large period of time from the 7th century to the 19th century. The contemporatry architure of Persian mosques are out of the scope of this study and there is no case study built in the 20th century or later.

They are all, except two, from arid and semiarid climate. Only Babol and Sari congregational mosques are from the south of the Caspian Sea with the subtropical climate. There is no sample from the south and the southeast of Iran, due to lack of reliable information about their mosques and more importantly about their plans.

3.4.1   *Abhar Congregational Mosque*

Abhar is a city in the west of Iran, between Ghazvin and Zanjan, on the way between two important cities, Tehran and Tabriz. The building of its mosque (Figure 3- 22) dated back to the 11th century (Haji-Qassemi ed., 2004b). Its construction was badly damaged and just recently, it was repaired and restored.
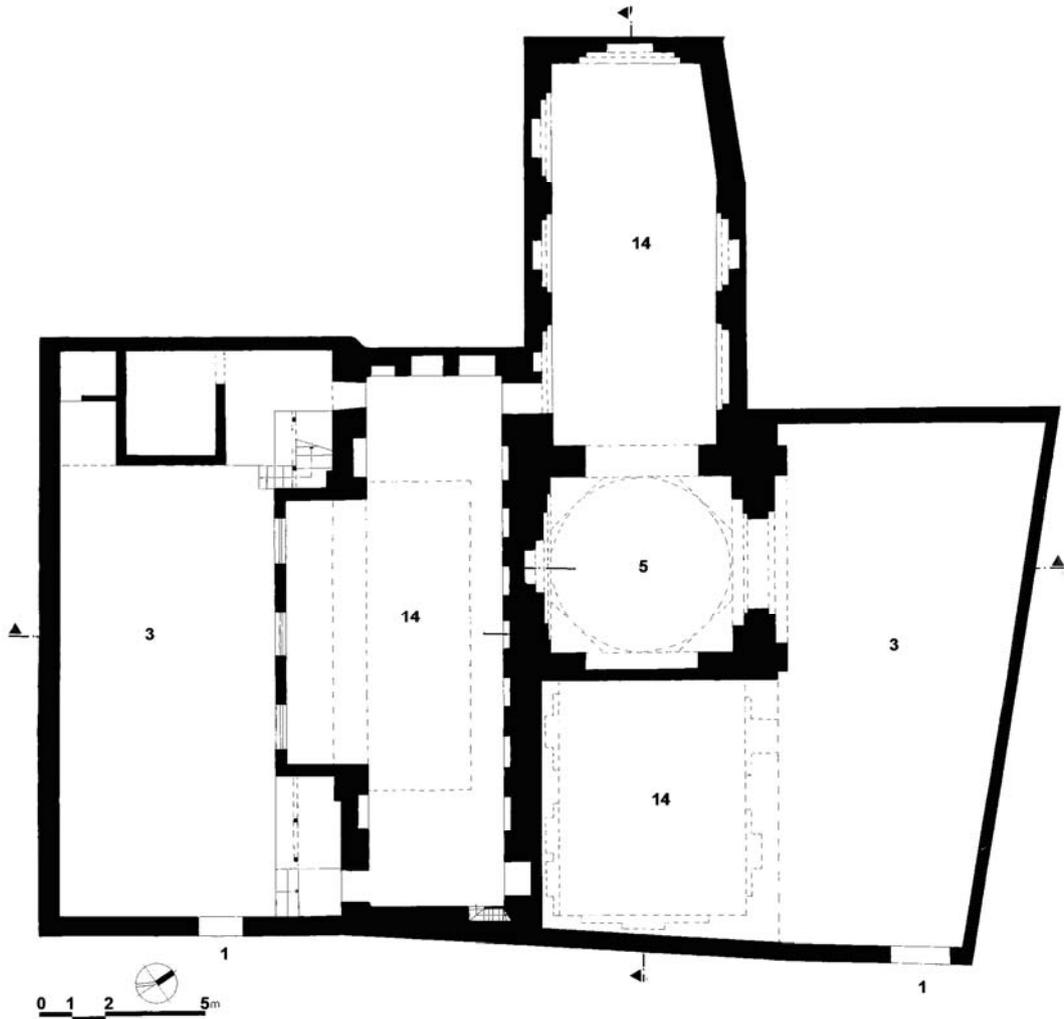

Figure 3- 22: Abhar Congregational (Jame or Friday) Mosque; and spaces in the plan are: (1) Entrance, (3) Courtyard, (5) Gonbad-khaneh, and (14) Prayer hall.

3.4.2 *Ardestan Congregational Mosque*

Ardestan is located in the middle of Iran, in Esfahan province. It seems that its mosque originally belonged to the Seljuk period, probably built on the site of Sasanian construction and later it was transformed to a four-eivan type (Haji-Qassemi ed., 2004b). The first enlargement of the mosque occurred in the south of the building and a few years later the shabestan design was fundamentally altered and the mosque was enlarged. However, these new spaces are shown with grey colour in the plan and are not included in the shape grammar analysis of chapter five.
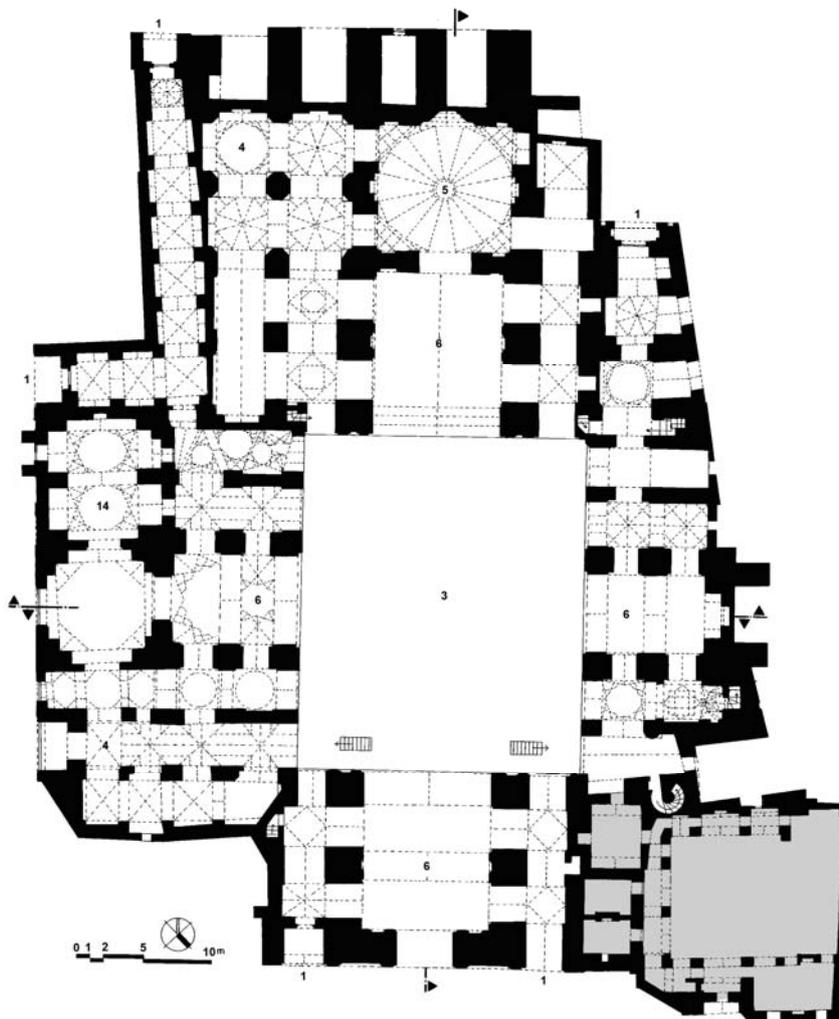
Figure 3- 23: : Ardestan Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (9) Chamber, and (14) Prayer hall. The grey area is not included in the shape grammar analysis.

3.4.3   *Babol Congregational Mosque*

Babol is a city in the north of Iran, south of Caspian Sea. Based on some ancient documents, the original building of the mosque belonged to the first period of the growth of the city in the eighth century and renovated in the Safavid period (Haji-Qassemi ed., 2004b, p. 112). After an earthquake in the Qajar period, the mosque was reconstructed again and later, the northern and southern eivans were covered by steel windows.
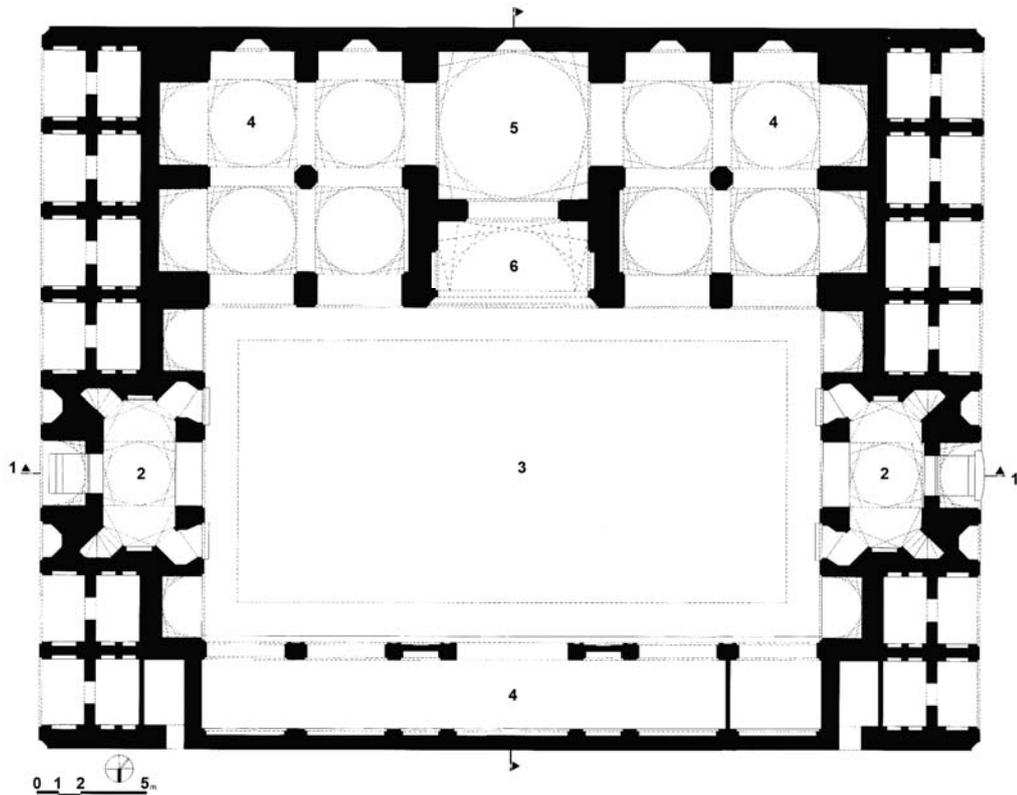

Figure 3- 24: Babol Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (9) Chamber, and (14) Prayer hall.

3.4.4   Boroujerd Congregational Mosque

Boroujerd is a city in the west of Iran. According to Haji-Qassemi (2004b, p. 106), its mosque was erected on the site of a ruined fire temple and it is believed that it had been built in the ninth century. However from sixteenth century since present, the building has been continuously repaired and altered.
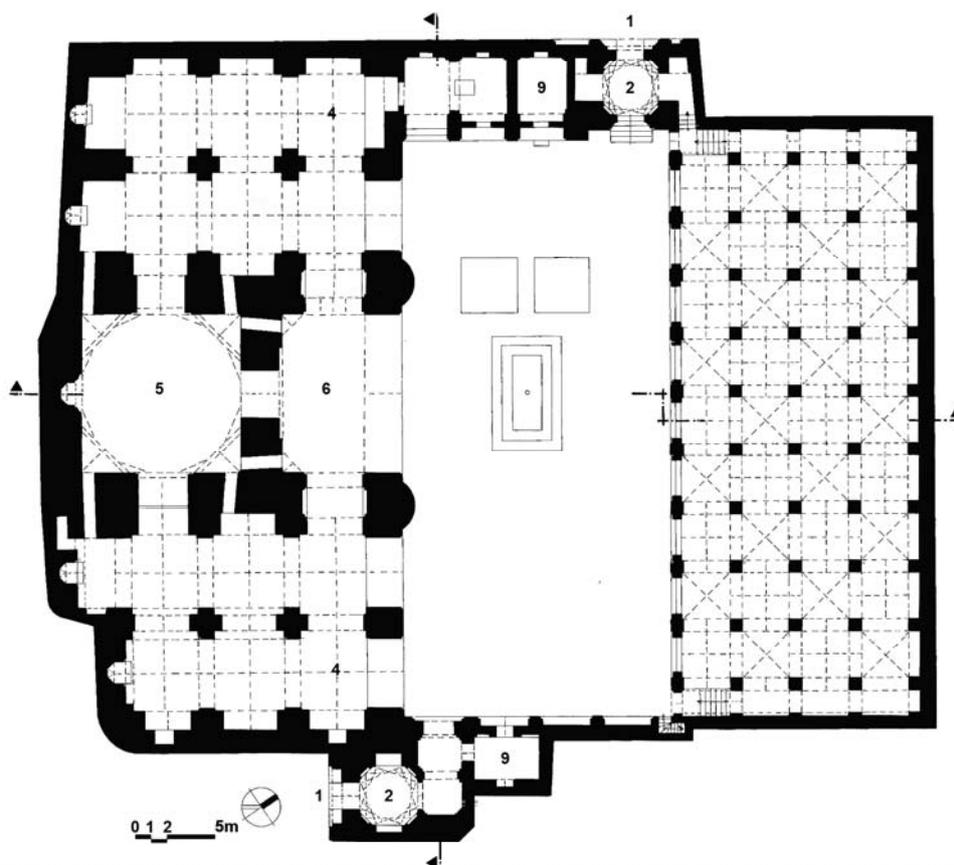

Figure 3- 25: Boroujerd Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (9) Chamber, and (14) Prayer hall.

3.4.5 *Chaleshtor Congregational Mosque*

Chaleshtor is a village in central Iran, famous for its rugs and arts. Its mosque was built in the first half of 19th century, but it has been rebuilt and restored several times. However, the latest plan will be used for analysis of chapter five. Lately, the southern side of the courtyard has been covered with metallic windows.
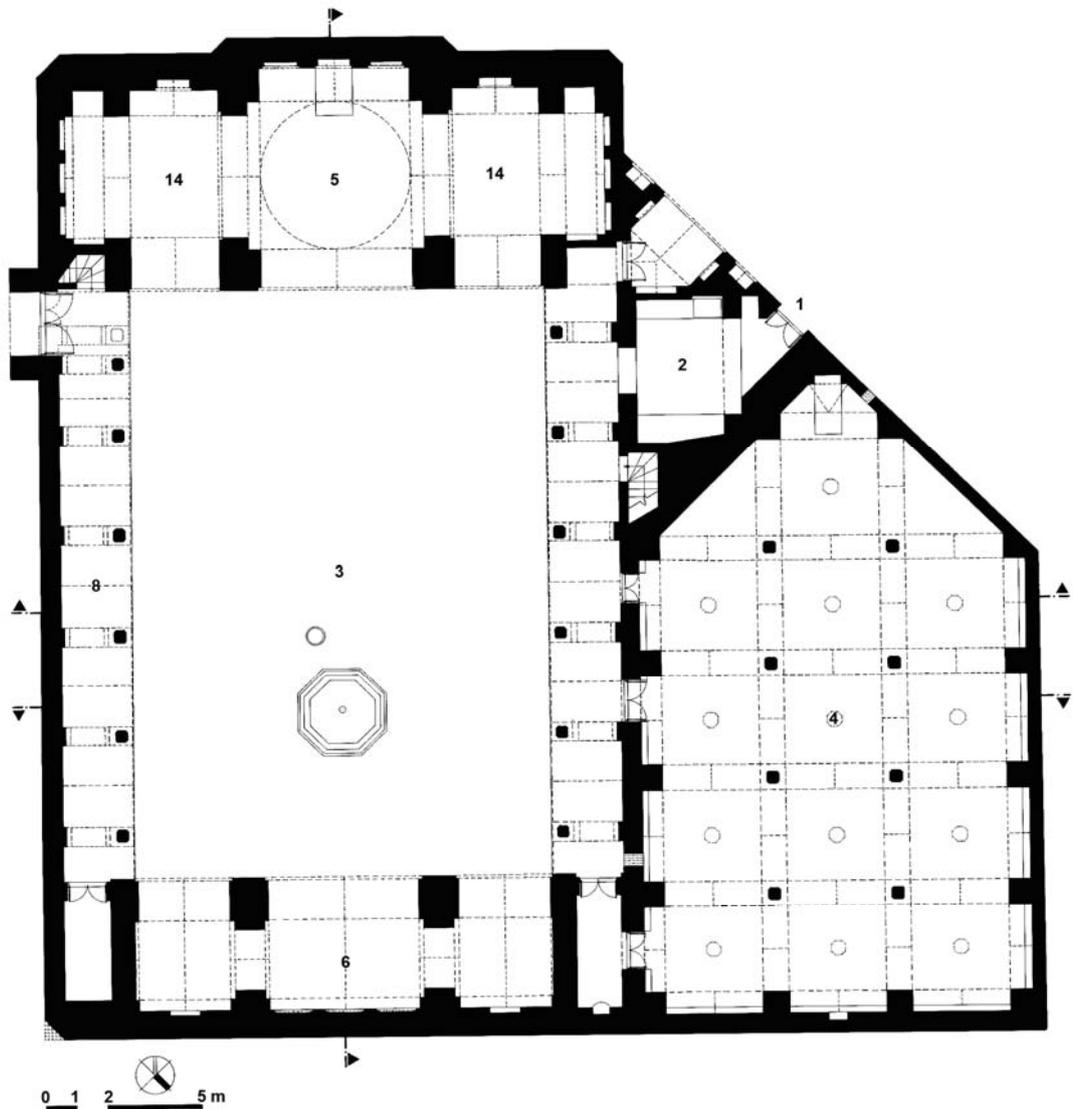

Figure 3- 26: : Chaleshtor Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (8) Colonnade, and (14) Prayer hall.

3.4.6   Damghan Congregational Mosque

Damghan is a city in the east of Tehran, in the Semnan Province. The original date of construction goes back to the early Islamic centuries, but it has been repeatedly restored and rebuilt in the course of time. In recent years, the southern colonnade was restored. The grey areas in the plan have been added during the Pahlavi period and are not included in the shape grammar analysis.
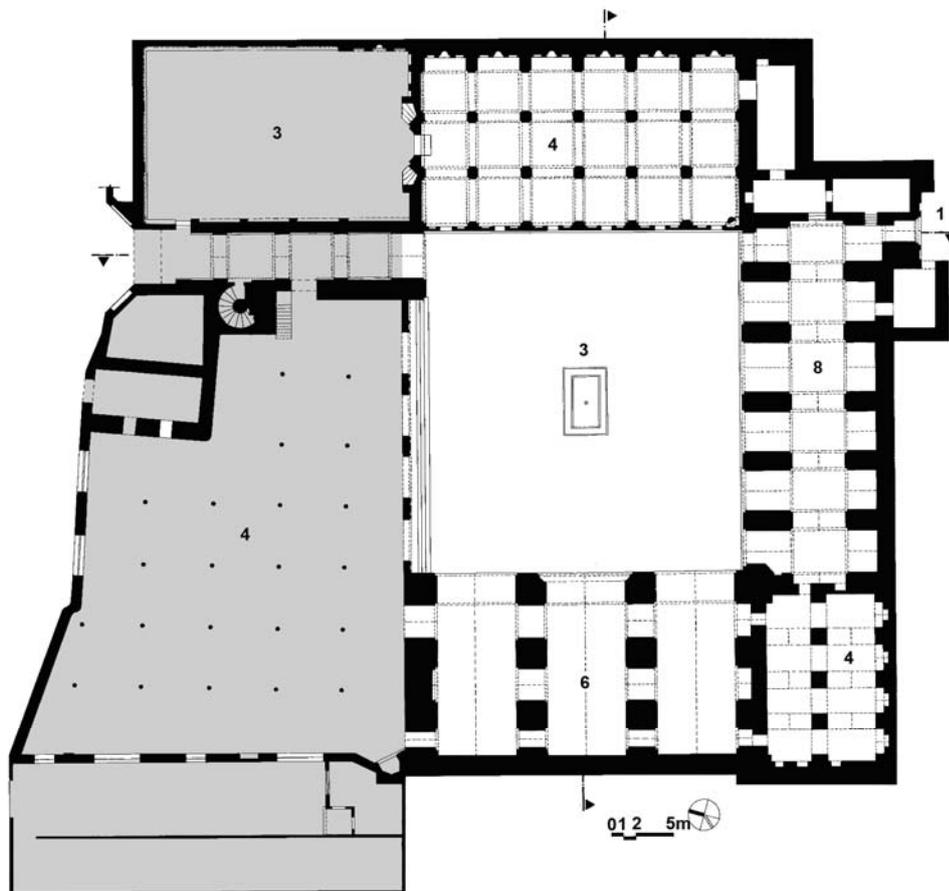
Figure 3- 27: Damghan Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (6) Eivan, (8) Colonnade, and (14) Prayer hall. The grey area which have been added recently is not included in the shape grammar analysis.

3.4.7 Dezful Congregational Mosque

Dezful is located in the southwest of Iran. According to some historic documents, the oldest part of this mosque dated back to 9th century and the large southeast shabestan was added to it in the 13th century (Haji-Qassemi ed., 2004b, p. 68). Recently, the mosque was thoroughly repaired and its portico (or colonnade) and the entire northern side were rebuilt with completely new portions and dimensions.
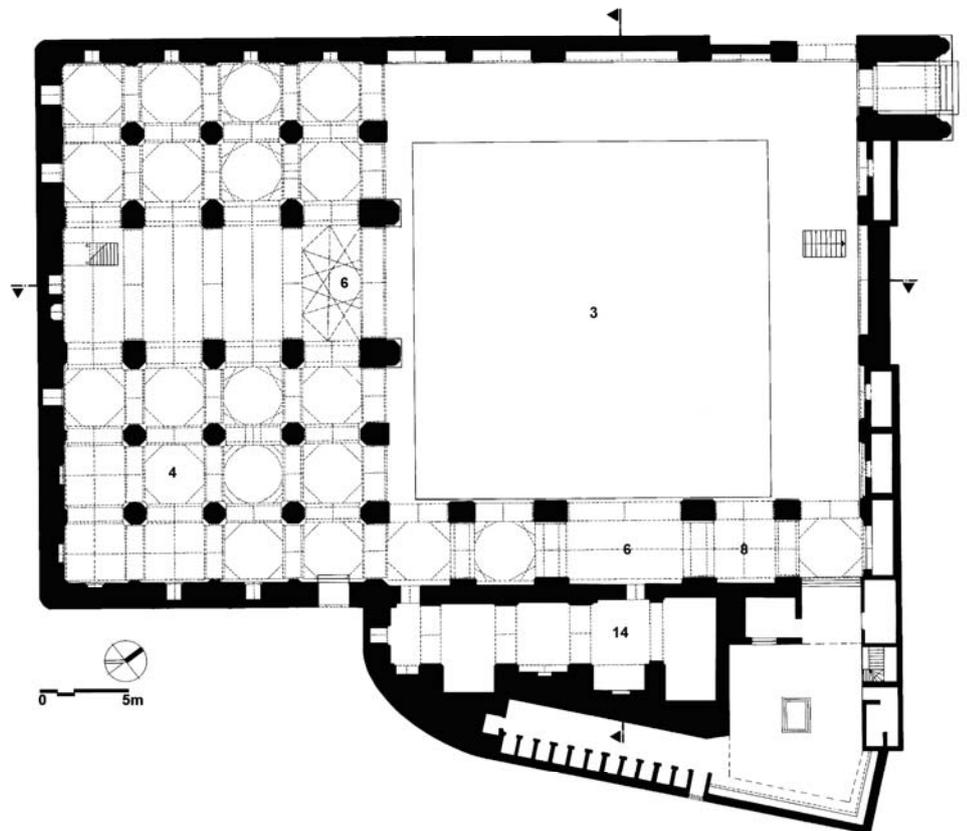

Figure 3- 28: Dezful Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (8) Colonnade, and (14) Prayer hall.

3.4.8   Orumiyeh Congregational Mosque

Orumiyeh is a city in the northwest of Iran. According to some documents, (Haji-Qassemi, 2004, p. 154) the building of gonbad-khaneh area of this mosque dated back to the Saljuqid period, however the mosque building consists of various parts built or restored in different periods. In recent decades, the chambers on the southern side of the courtyard have been removed and four chambers in front of the gonbad-khaneh demolished and, the eastern side of the building was demolished and replaced by a large hall. Therefore, these spaces shown by grey colour in the plan are not included in the shape grammar analysis in chapter five.
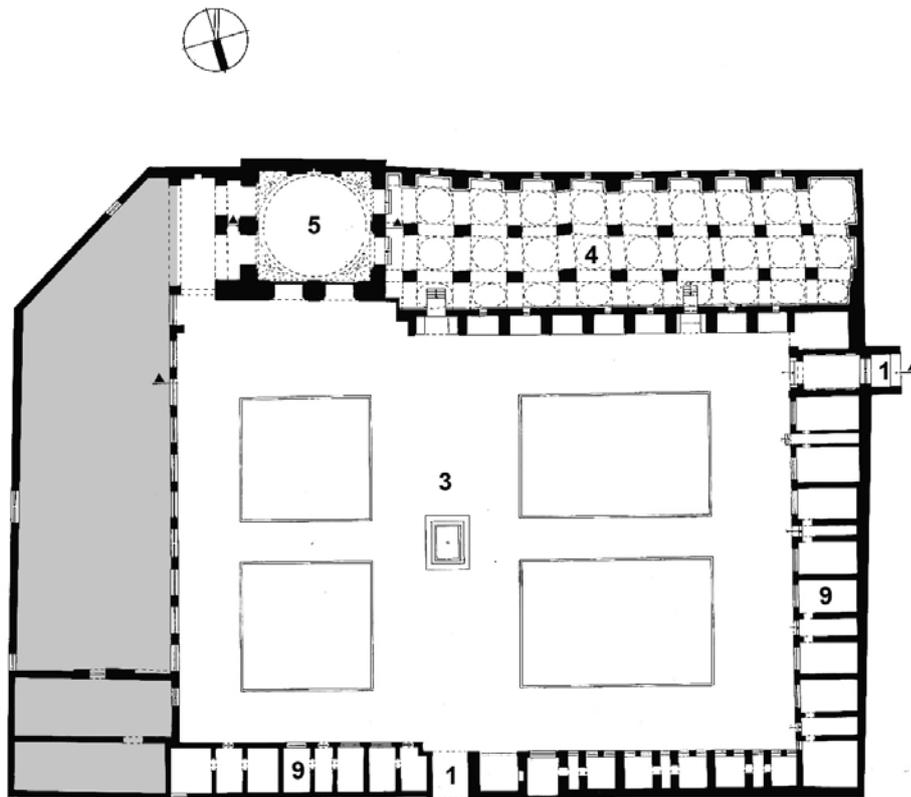
Figure 3- 29: : Orumiyeh Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (9) Chamber, and (14) Prayer hall. The grey area added recently is not included in the shape grammar analysis.

3.4.9   Oshtorjan Congregational Mosque

Oshtorjan is a village in the southwest of Esfahan and has a noteworthy medieval congregational mosque (Pope, 1973). This mosque is significant for its architecture, decoration, and epigraphy; it comprises a dome chamber, and a small courtyard with uneven lateral prayer halls. Based on its tile work from 14th century, it seems that the mosque foundation belongs to Seljuk period, but most of the present building is from reconstruction and enlargements of the Ilkhanid period (Haji-Qassemi ed., 2004b).
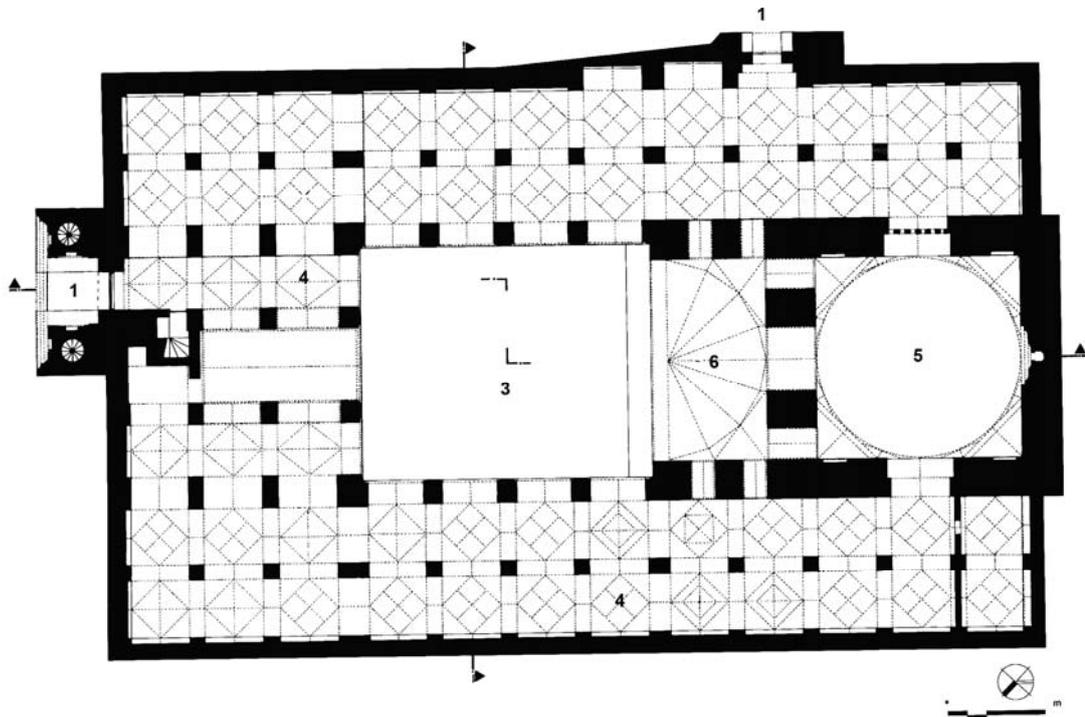

Figure 3- 30: Oshtorjan Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, and (14) Prayer hall.

3.4.10 Sabzevar Congregational Mosque

Sabzevar is located in the northeast of Iran. The oldest script on the building of this mosque (Figure 3- 31), in a corridor in the east of northern eivan, belongs to Safavid period. However, other dates have been written on the other parts of the building too. Therefore, there are different views about the original date of construction. Some scholars based on some scripts think that the mosque belongs to 11th century, but the building has been repeatedly repaired and restored so it is hard to be specific about the date of the construction.
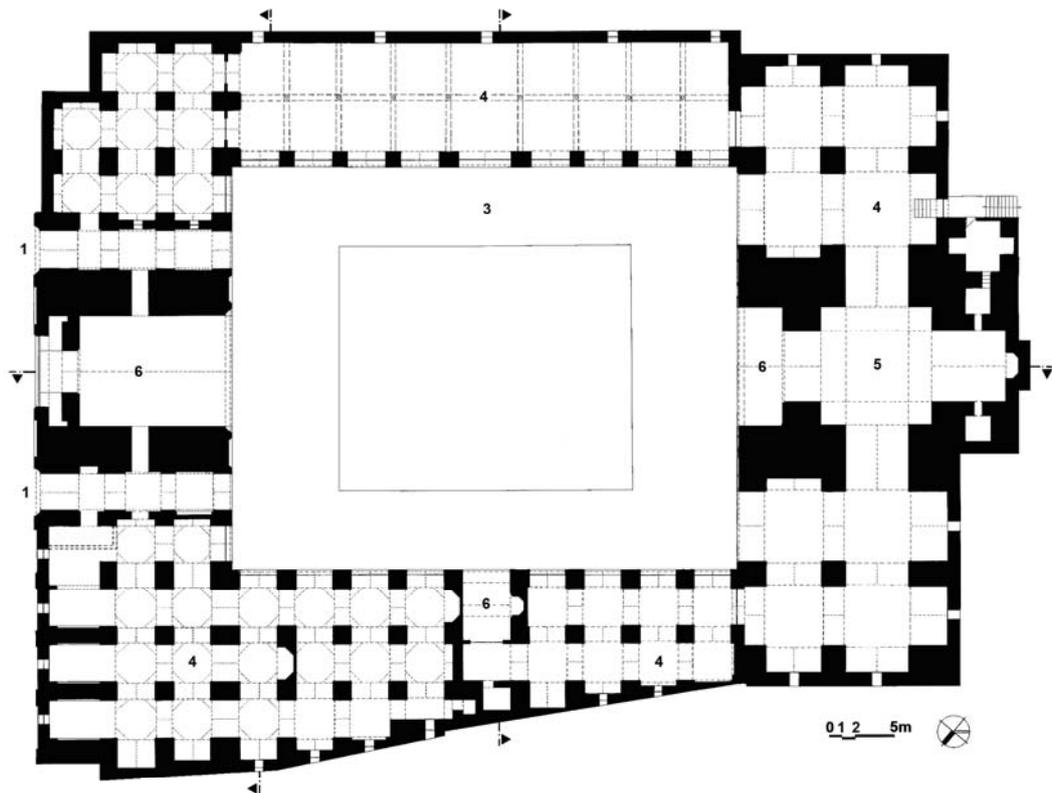
Figure 3- 31: Sabzevar Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, and (14) Prayer hall.

3.4.11 Sanandaj Congregational Mosque

Sanandaj is in the west of Iran and the capital of Kurdistan province in the west of Iran. The façade of its congregational mosque (Figure 3- 32) has a text which indicates 1848 as the date of completion of the building; therefore it belongs to Qajar period. The building was restored and some parts such as minarets were rebuilt in 1963. Later during the construction of an adjacent avenue, the southern side of the mosque was damaged and was rebuilt as present. In this plan, the chambers and lecture hall have all the characteristics of prayer hall, therefore they are considered as prayer hall in the shape grammar analysis.
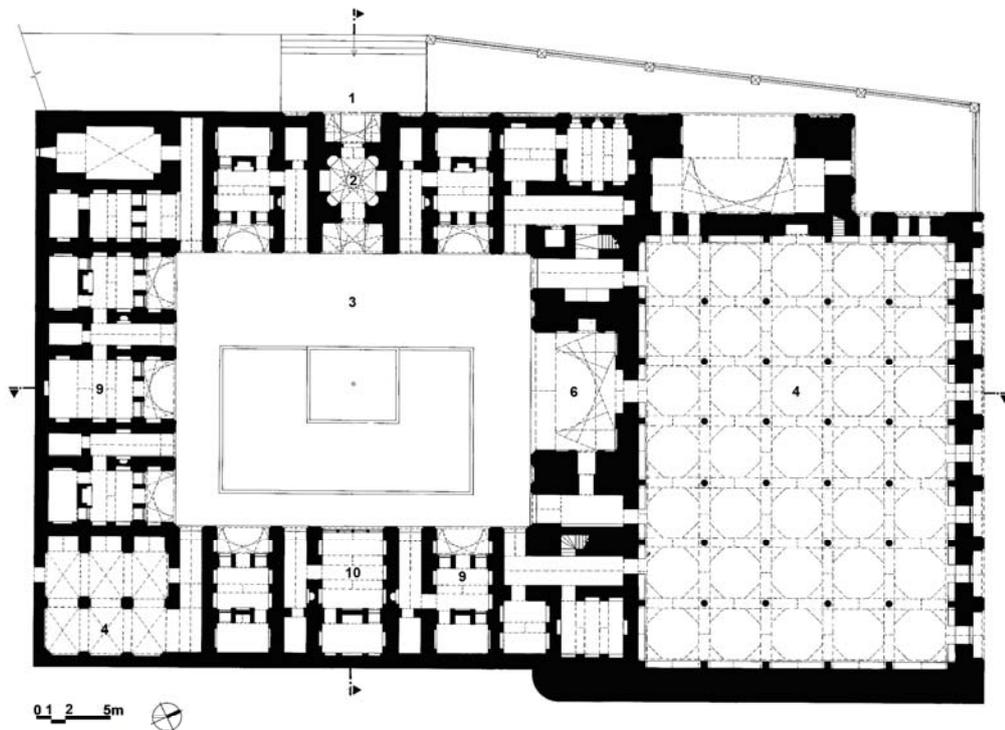

Figure 3- 32: Sanandaj Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (9) Chamber, (10) Lecture hall, and (14) Prayer hall.

3.4.12 Sarab Congregational Mosque

Sarab is a city in the northwest of Iran, in the East Azerbaijan province of Iran. This mosque has a very simple plan. The east entrance of this mosque bears the date of 1470; however, there are some suggestions that its recent construction date might belong to 1750 to 1794 in the Zand dynasty instead. During Mogul period, the building of the mosque was damaged and its tiles were mostly broken.
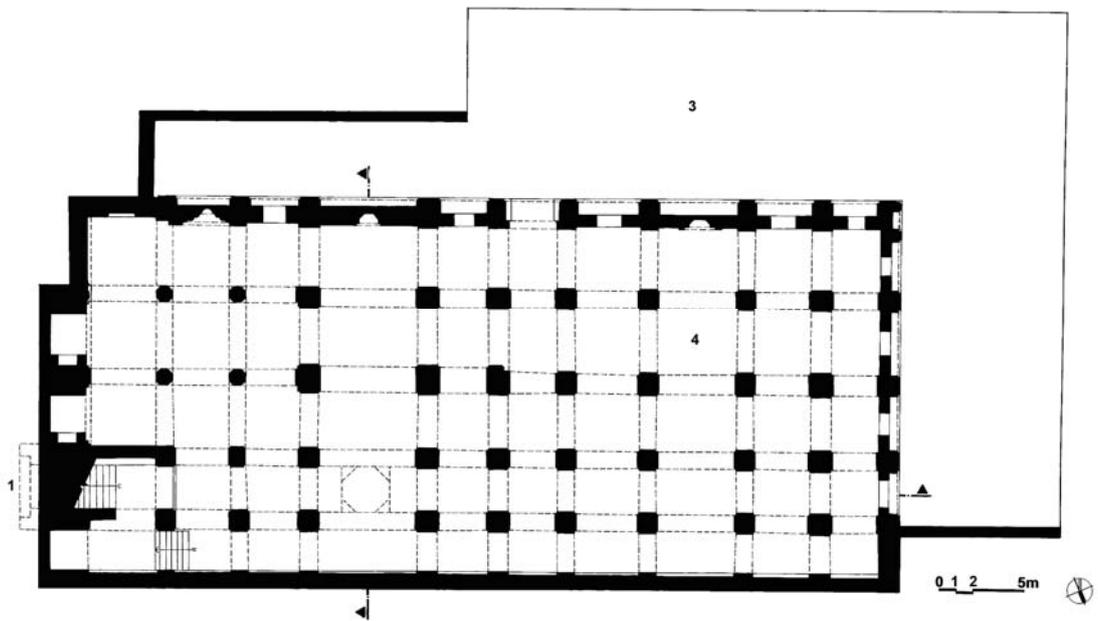
Figure 3- 33: Sarab Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, and (4) Shabestan.

3.4.13 Sari Congregational Mosque

Sari is in the south of Caspian Sea and the capital of Mazanderan province in the north of Iran. The construction of this mosque dates back to early Islamic centuries; however it has been repaired and altered so many times. (Haji-Qassemi ed., 2004b)
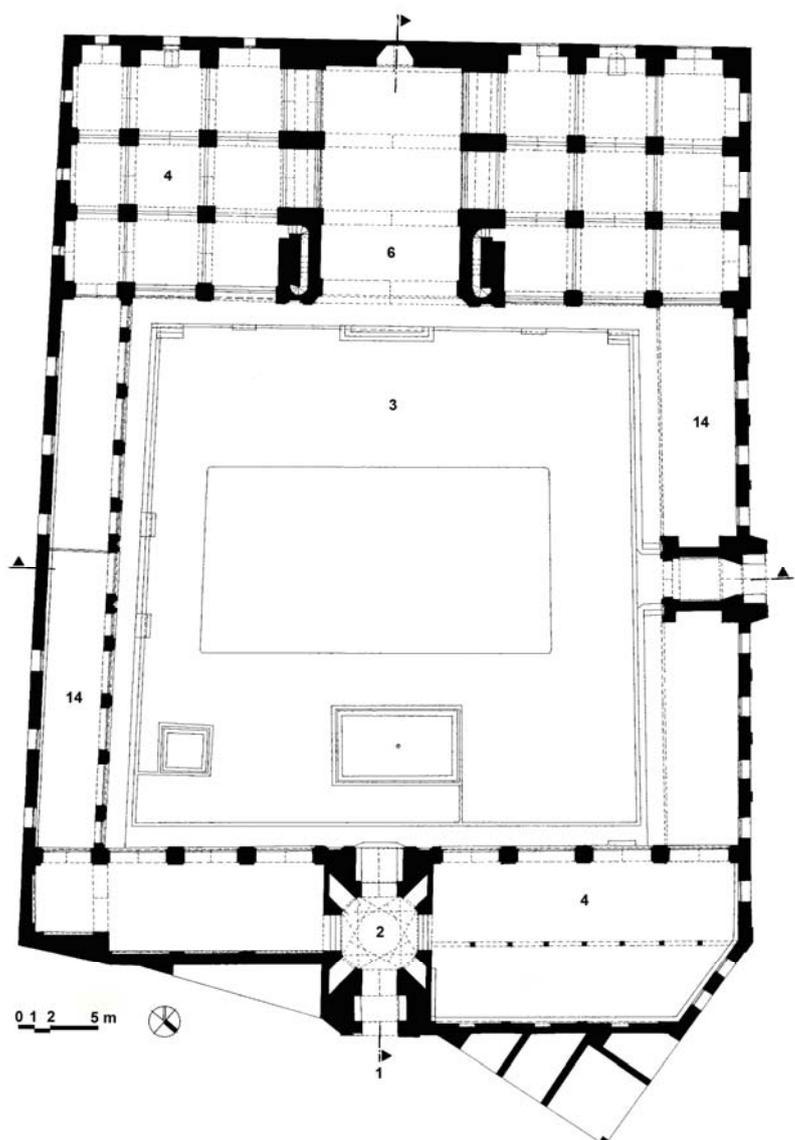

Figure 3- 34: Sari Congregational Mosque; and spaces in the plan are : (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, and (14) Prayer hall.

3.4.14 Saveh Congregational Mosque

According to some scripts on the façade, this mosque belongs to 9th century. "Judging by the remaining parts, it appears that another building existed prior to the construction of the mosque and it was tamped down to form the base of the existing building (Haji-Qassemi ed., 2004b, p. 40)." In the course of the time, its building had gone through various changes and so many parts were added or demolished and at the moment, the mosque is subject to ongoing archaeological research.
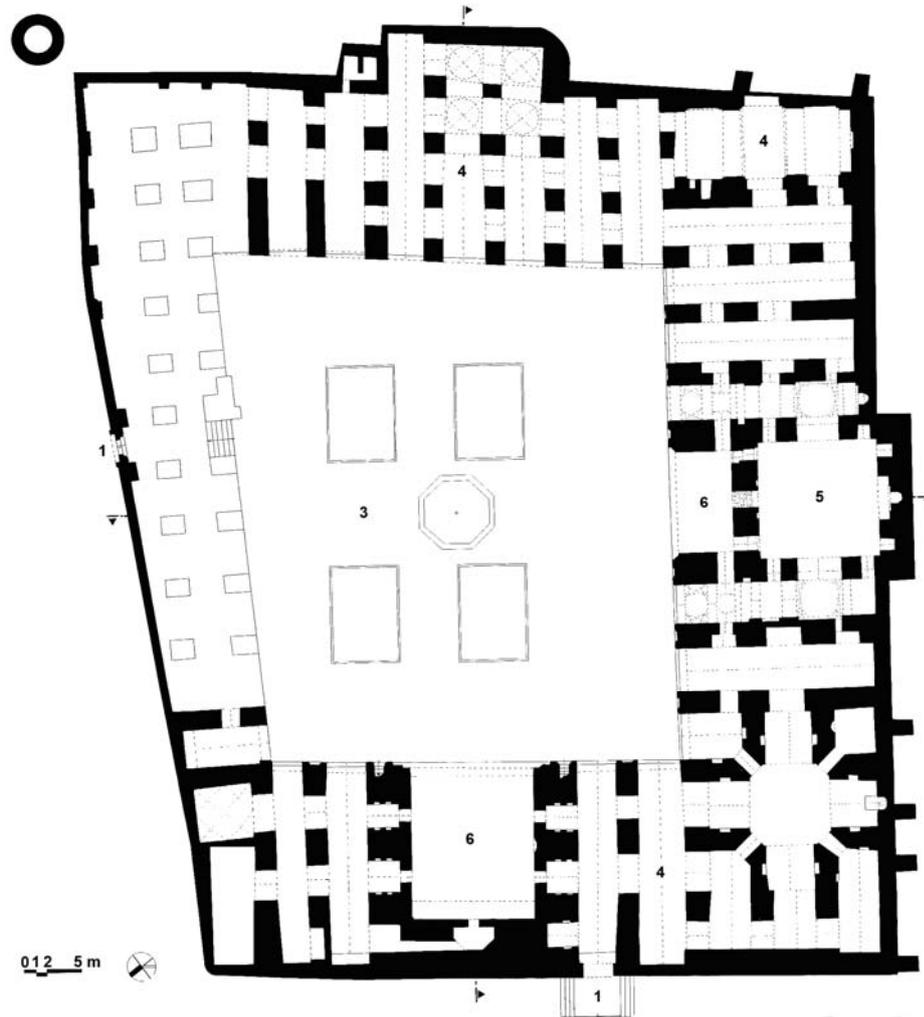

Figure 3- 35: Saveh Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, and (6) Eivan.

3.4.15 Tabriz Congregational Mosque

Tabriz is the fourth largest city of Iran and the capital of East Azerbaijan Province in the northwest of Iran. The name of its mosque has been mentioned in different documents during Mogul period and the oldest inscription on its wall is dated 1564. However the present mosque is an ensemble of different buildings created or rebuilt in various periods; for example the prayer hall has been repaired and altered repeatedly and its exact construction date is unknown. Beside this mosque, two religious schools exists which belongs to the mosque, but they are out of the scope of this research and will not be included in the analysis of the chapter five.
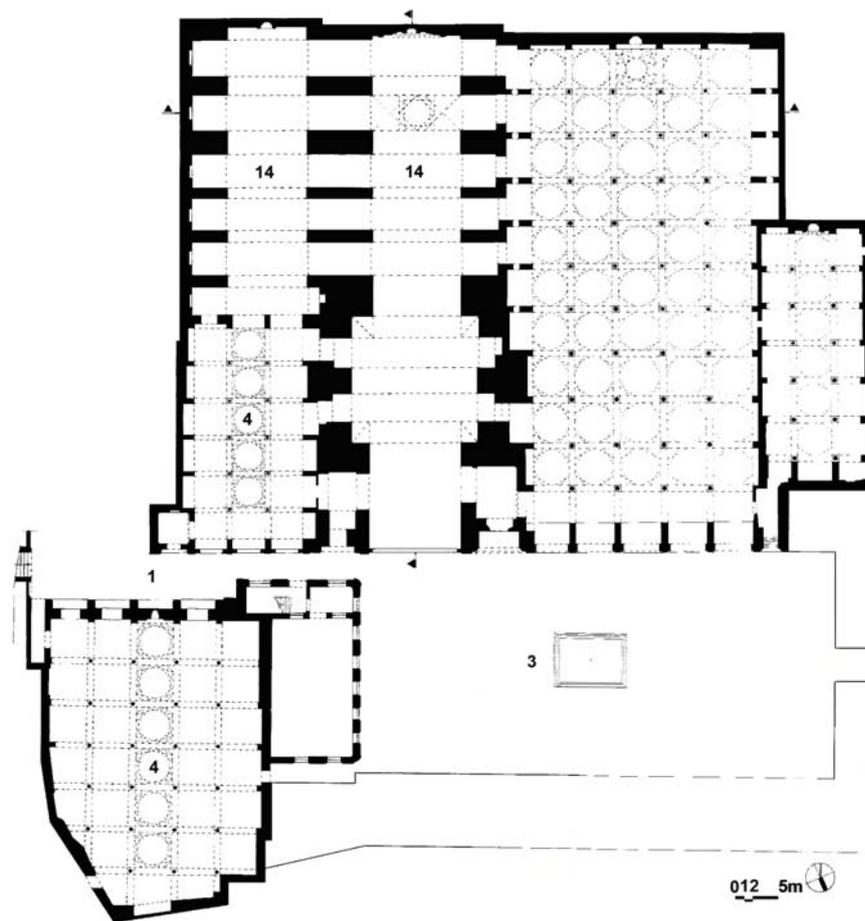

Figure 4- 34: Tabriz Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, and (14) Prayer hall.

3.4.16 Tuyserkan Congregational Mosque

Tuyserkan is a city in the south of Hamadan, west of Iran. The date of this mosque's construction (Figure 3- 36) is unknown, but an inscription on its minaret indicates the date 1854. Recently, some spaces were added to western side of the courtyard and the second floor has been added to the building. These spaces which are shown with grey colour in the plan are excluded from the analysis of chapter five.
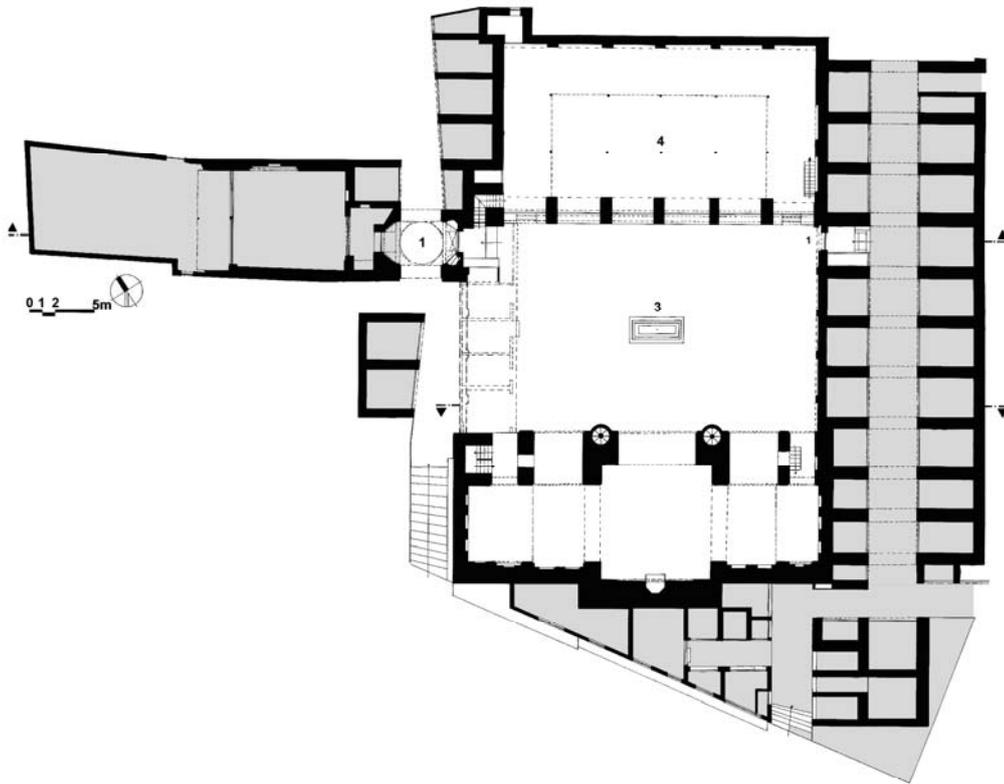

Figure 3- 36: Tuyserkan Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, and (4) Shabestan. The grey areas in the plan are not included in the analysis.

3.4.17 Zanjan Congregational Mosque

Zanjan is located in the northwest of Iran. No historic inscription exists in this mosque, but according to Haji-Qassemi (2004b), the construction of the mosque (Figure 3- 37) seemed to be dated back to 1858. In the Pahlavi period, when an avenue was built on the northern side of the mosque, its entrance was altered and the vestibule behind the northern eivan was demolished (Haji-Qassemi ed., 2004b). In recent years, eivans have been restored and some of the main spaces of the mosque around the courtyard have been used for chambers and vozu-khaneh (space number 12). Vozu-khaneh is used for ritual ablutions before prayers and often located in the service areas.

Figure 3- 37: Zanjan Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (9) Chamber, (12) Vozu-khaneh, and (14) Prayer hall. The grey area is not included in the shape grammar analysis.

The grey area in the plan belongs to Bazaar next to the mosque, so it will not be included in the shape grammar analysis of the chapter five.

3.4.18 *Zavareh Congregational Mosque*

Zavareh is a small town in the northeast of the Esfahan province, near Iran's central desert area. According to Haji-Qassemi (2004b), the present mosque (Figure 3- 38) belongs to 12th century, but shabestan and some other parts were added in the later periods.
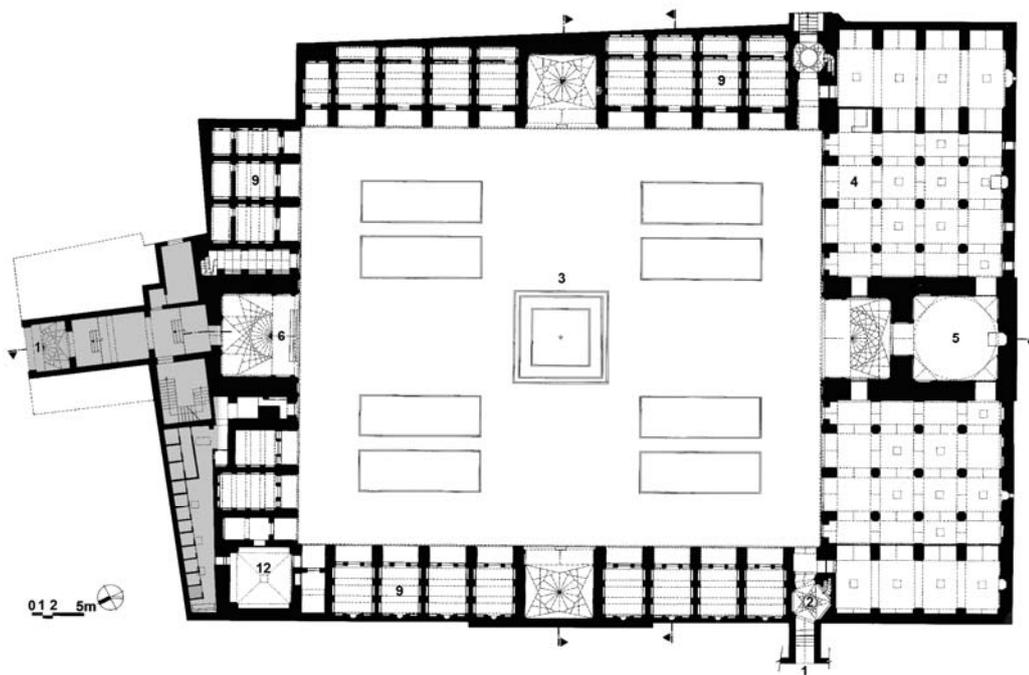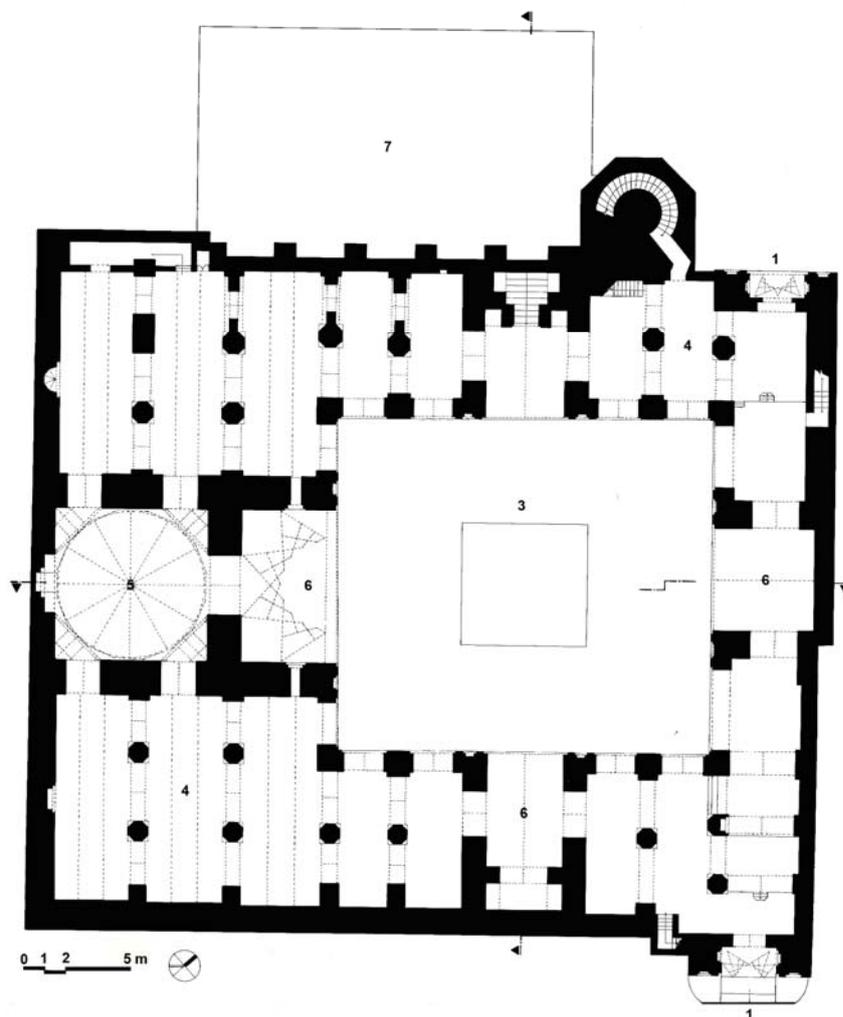

Figure 3- 38: Zavareh Congregational Mosque; and spaces in the plan are: (1) Entrance, (2) Vestibule, (3) Courtyard, (4) Shabestan, (5) Gonbad-khaneh, (6) Eivan, (7) Mahtabi, and (14) Prayer hall. Mahtabi is not a part of the mosque, thus out of the scope of this analysis.

3.5   Summary

The most common monuments of Persian Islamic architecture are primarily religious: large congregational mosques, small mosques, and schools. Most of these functions are typical among all Islamic countries. However, each region of the Islamic world, including Persia, had created a stylistic image of its own, based on local material, craft skills, climate and other factors. Here, Persian mosques were considered.

No classification system for architecture of Persian mosques exists. Only the history of the Persian architecture and Persian mosques has been studied. Detailed historical accounts on Persian architecture are given by Pope (1965), Frishman (1994), Haji-Qassemi (1998, 2004a and 2004b), Yarshater (2006) and Hillenbrand (2009). However, these attempts have been partial satisfaction, as they only described the history and the motivation behind Persian architecture in general and Persian mosques in details. Perhaps the best study, in this context, is Frishman's book based on different articles from different authors. However, none of these sources tries to categorise Persian Mosques which is the purpose of this study.

It seems that three important factors have influenced the development of Islamic architecture in Iran. Firstly, many architectural techniques and purposes remained as before Islam in the Sasanian period. The second is that Islam brought one new architectural function: the mosque, and hypostyle hall for mosques in Iran. Finally, a number of pre-Islamic monumental and official forms like the eivan and the dome and decorative techniques like stucco were immediately adopted for Islamic buildings and spread all over the Muslim world. However, this conclusion is only of limited help in the understanding of Islamic architecture in Iran.

The aim of this research is to classify Persian mosques and their elements with respect to their formal, functional properties for the first time. As was mentioned here, mosques are social, and religious objects that carry meanings for society in

general, and users in particular. Texts are often used both to describe and to prescribe them. But in order to avoid the perceptions and limits of the observer in the categorisation, the shared characteristics are studied by shape grammar, rather than texts.

Shape grammar is a sophisticated and useful method that helps architecture to move away from intuitive analysis methods toward more structured ones. In the next chapter, this method will be discussed in details.

Chapter 4: Shape Grammar

4.1   Introduction

Shape grammar is a well-established formalism for analysing members of a class of designs in order to reveal their complex designs and styles. They are one of the earliest algorithmic systems for understanding designs directly through shapes, rather than indirectly through text or symbols. As this type of analysis is based on well-defined abstract geometry, the analysis is drifting away from the intuitive processes. Over the years, Shape grammars theory has evaluated and has been successfully used for analysing and describing existing designs in numerous projects.

In the analysis applications of shape grammar, recognizing spatial relations between shapes occurring in designs provides the foundation for a precise, logical discussion of their formal characteristics and structure. Then; these spatial relations are used as the foundation for constructing designs whose formal characteristics and structure are known. In the present research, shape grammar has been used for analysing and categorising Persian mosques.

In this chapter, a brief explanation of shape grammar, its history and its applications will be discussed.

4.2   shape grammars history

One formal approach to the architectural design was the systematic exploration of alternative ways (Figure 4- 1) in which various elements from a fixed vocabulary could be assembled in different combinations to generate architectural forms.
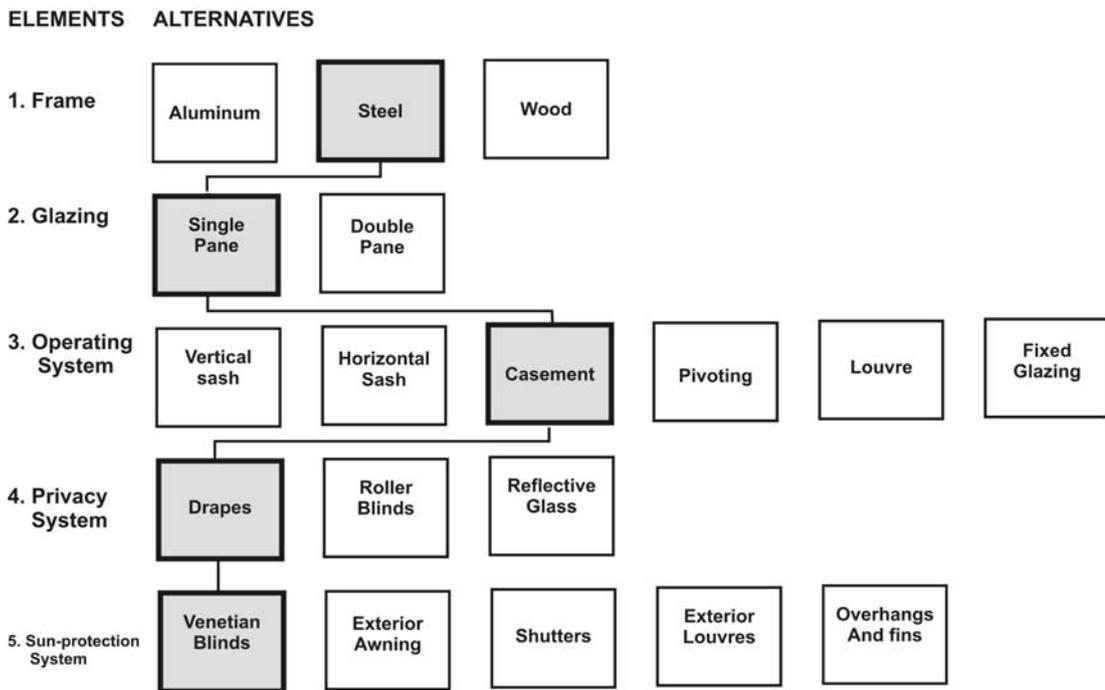

Figure 4- 1: An example of morphological chart for designing of a domestic window which alternatives for each essential element of design are arranged in parallel rows (Mitchell, 1975)

In the 1972, shape grammar was invented by Stiny and Gips; and for the first time Stiny (1976) showed the potential of shape grammars. In this paper, he illustrated many applications of shape grammars which became the foundation of many works that followed. In the first part of this paper, Stiny used shape grammars to create new design languages; then in the second part, shape grammars were used to analyse known and existing designs. Both of these exercises showed the unique characteristics of the shape grammar formalism that helped motivate shape grammar work. Then over the years, shape grammars have been explored through these applications addressing a variety of design problems.

Later, Stiny (1980b) examined the kindergarten method of Frederick Froebel. These shape grammars were the first defined in a three-dimensional space. However, the

kindergarten programme for creating original grammars was not used for several years while analytic applications of shape grammars grew quickly.

Shape grammars have been used in the architectural field to develop designs, such as Palladian villas (Stiny & Mitchell, 1978a & 1978b), Prairie houses (Koning & Eizenburg, 1981), and Ottoman style houses (Colakoglu, 2005). But the use of shape grammars is not only limited to the architectural field. They have also been used for designs such as window lattice designs in the Ice-ray grammar (Stiny, 1977), Froebel block arrangements in the Kindergarten grammar (Stiny, 1980b), coffee makers in the Coffee maker grammar (Agarwal & Cagan, 1998), and landscape grammar (Mayall & Hall, 2005 & 2007). Each of these grammars generates a design by using a particular technique of the shape grammar formalism.

4.3 Applications of shape grammars

Over the past decades, shape grammars have been used for analysing of an existing body of work which can have a wide variety from architecture to product designs, for creating new designs in the existing style, for transforming an existing style into a new one, and for developing a new language of forms. In brief, shape grammars have been used to answer two fundamental concerns in design: (1) the description and the analysis of past or present designs, and (2) the creation of completely new and original designs. Here, the applications of shape grammars are discussed:

4.3.1 Applications of shape grammars in analysis

In the analytical usage of shape grammar, the process consists of beginning with a given arrangements of spatial elements and constructing or identifying additional arrangements of these elements that are in the same style. Firstly, the given form could be decomposed into its principal and secondary elements and then these elements with the principal one be recombined in as many new ways as possible (Stiny, 1976). In fact, shape grammars have found so many applications in the architectural analysis that they can most easily be thought of as a type of systematic analysis system based on geometry.

The use of shape grammars for analysis has a long history. Stiny (1977) used shape grammars for analysing Chinese lattice designs. This paper was the first complete example of analytic practices with shape grammars. The second exercise (Stiny & Mitchell, 1978a & 1978b) was more complex and initiated the more ambitious applications of shape grammars in analysis. And for the first time in 1981, Koning and Eizenberg produced the language of Frank Lloyd Wright's prairie houses in three-dimensional grammars.

These are only few examples of analytic applications of shape grammars in architecture and landscape architecture, such as: Mughul gardens (Stiny & Mitchell, 1980), the architecture of Casa Guiliani Frigerio (Flemming, 1981a), Japanese tearooms (Knight, 1981), bungalows of Buffalo (Downing & Flemming, 1981), the Work of Architect Glenn Murcutt (Hanson & Radford, 1986), Queen Anne houses (Flemming, 1987), Wren's language of City church designs (Buelinckx, 1993), Taiwanese traditional vernacular dwellings (Chiou & Krishnamurti, 1995b), traditional Turkish houses (Cagdas, 1996), Siza's Malagueira houses (Duarte, 2005), Ottoman style hayat houses of Sarajevo (Colakoglu, 2005) and Patio houses of Marrakech (Duarte & Rocha, 2006). In these studies, shape grammars have been used to study historical buildings. However, these analyses did not include historical developing of buildings or the influence of climate in their designs.

Shape grammars have also been used for analysis in arts and designs, such as: Hepplewhite-style chair back designs (Knight, 1980), the paintings of Richard Diebenkorn (Kirsch J. L. & Kirsch R. A., 1986), ancient Greek pottery (Knight, 1986), the paintings of Georges Vantongerloo and Fritz Glarner (Knight, 1989a), and the windows designs of Frank Lloyd Wright (Rollo, 1995).

These widespread usages for analytical purposes made shape grammars as an established method in computer-aided design and design theory. Shape grammars have succeeded in analysis applications because of: (1) their direct handling of and reasoning about geometry, (2) their ability to operate on a geometric representation, and (3) their ability to support emergence of shape (Agarwal & Cagan, 1998). Geometry is critical to systematic analysis in architecture; and a finite set of rules enables an infinite number of designs; and emergence indicates the possibility of enabling creative design within in a fixed set of shape grammar rules. These advantages suggest why shape grammar has succeeded where other knowledge-based representations and methods have failed.

4.3.2   Applications of shape grammars in original design

Shape grammars have also been used to create new and original designs. In 1972, Stiny and Gips published their first paper about shape grammars; and in this paper, they used shape grammars for original languages of paintings. These shape grammars are used for interpreting and evaluating paintings. However, this application of shape grammars was not used by other scholars for a number of years until it was completely presented by Stiny (1980b) in "Kindergarten grammars: designing with Froebel's building gifts". These shape grammars are defined in a three-dimensional space for the first time.

4.3.3   Applications of shape grammars in analysis and designs

Just like architecture design itself, only very few shape grammars starts from scratch; and in practice, original languages are mostly created from past or known designs, rather than from scratch. In other words, original designs generally involve some degree of understanding and analysis of known designs.

In this way, the shape grammars are used as a generator for creating new ideas, instead of conventional methods, but the first stage is to analyse a design or some parts of it and extract rules from it; and in the next stage, new design possibilities are created by these rules. Finally, one or more possibilities are selected for further development. Thus, this method is both analytic and creative.

Knight (1981b, 1983a, 1983b & 1983c) proposed a model for developing new designs on the basis of existing ones. In these papers, she suggested a known language is first analysed by extracting a grammar for it and then the rules of grammar are transformed and finally the transformed rules become the basis for a new grammar, and she (1994b) applied it in the works of Frank Lloyd Wright, in De Stijl painting, and in ancient Greek ornamental designs. In 1990, Flemming suggested a similar method for teaching architectural compositions. In this method, students learn some languages and their rules; then they modify the grammars of these languages to generate new languages. Mayall and Hall (2005 & 2007) have also used similar system to create landscape grammars. This grammar has been defined by vocabularies of landscape object types and spatial syntax rules and new landscape scenes can be generated through it.

This application of shape grammars has two advantages: (1) the known and historical styles could be characterised; and (2) this could be used to create new styles on the basis of existed ones.

Finally, it can be summarised that there are three places where shape grammars can be injected into the design process: (1) before the synthesis of a design, as an advisor; (2) after the synthesis of the design, as a critic; (3) and during the synthesis of the design, as a generator.

4.4 *Shape grammar*

Shape grammar plays an important role in defining the design rules in the architectural design processes, using knowledge-based design systems. Shape grammar is s set of shape rules that apply in a step-by-step way to generate a set, or a language of designs. These rules, which are descriptions of the forms of the designs, generate designs. The basis of shape grammar is the idea of capturing design knowledge in such a way that the generation of designs can be achieved.
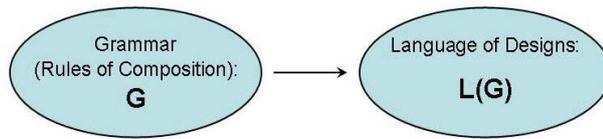
Figure 4- 1: Relations between grammars and language in shape grammar

4.4.1   Components of shape grammars

A shape grammar is founded on a vocabulary of shapes and a set of spatial relations that correspond to different arrangements of shapes in the vocabulary. A set of shape rules defined in terms of these spatial relations, together with a starting or initial shape made up of shapes in the vocabulary, comprise a shape grammar. The shape rules of a grammar are applied repetitively or recursively to the initial shape and to shape produced from it to generate designs in a language. The vocabulary of shapes and the set of spatial relations underlying a language generated by a grammar correspond to the familiar constituents of style.

In other words, Shape grammars are like natural languages that have their own vocabulary, syntax, semantics, context and styles. They consist of a starting or initial shape, a set of shape rules, and a final state. The shape rules apply recursively to the initial shape, and to shapes produced from it, to reach final design. The final state specifies when designs are in the language defined by the grammar. A grammar is a formal statement about the structure of the language or designs to be described.

Thus in this context, any design is a complex of shapes and relationships between these shapes. A design consists of vocabularies of shapes arranged according to specific spatial relations. Then, a shape is defined as a finite collection of lines, a vocabulary as a set of shapes no two of which are similar, and a spatial relation as a collection or arrangement of shapes. As different designs have different vocabularies of shapes and different spatial relations between them, each vocabulary and set of spatial relations in a shape grammar generate different language of designs. A shape

grammar generates a language of designs and the designs in this language are syntactically alike, as their compositions are governed by the same spatial relations.

When a group of designs has a particular style, a vocabulary of shapes and set of spatial relations common to all or almost all the designs can be distinguished. Shape rules based on these spatial relations grantee uniform recurrences of these spatial relations within the designs. A shape grammar, specified in terms of these shape rules, generates a language of designs which includes, at least, some or all of the designs in the group. Different syntactic interpretations of a corpus of designs determine different shape grammars which, in turn, usually produce different languages of designs.

In theory, shapes and spatial relations can be anything at all and are limitless in number. In practice, the constraints of a design problem and the constraints the designer brings to the problem motivate the selection of particular shapes and spatial relations. Therefore, the shapes and spatial relations which is used to compute designs often have hidden meanings and functions in the same way that, in a conventional design process, the lines a designer puts down on paper have meanings.

4.4.2   *Types of shape grammars*

Over the years, shape grammar theory has evaluated and now contains variety of shapes and shape computations. All of these extensions of shape grammar have been developed in order to compute different kinds of designs. In this section, some of these extensions will be discussed.

In 1977, Stiny introduced "parametric shape grammars". They compute designs with variable or parametric shapes. Later in his paper: "a note on the description of designs", he wrote about "description grammar". Like its name, it computes descriptions of design. And "Parallel grammars" (Stiny, 1990) or grammars defined in multiple algebras simultaneously compute different shape, text, or symbolic representations of designs. These shape grammars are briefly explained here:

4.4.2.1 Basic shape grammars

In basic grammars (Figure 4- 2), all rules are addition rules. An addition rule is a rule that adds a shape (labelled in any way) in accordance with a particular spatial relation. Rules are linearly ordered and each rule applies under one similarity transformation to the labelled shape added by the previous rule.

In this type of shape grammars, only one derivation is possible. The simple way in which a basic grammar works allows designs to be characterized in terms of the shapes added by the rules. There are no subtraction rules in a basic grammar. Basic grammars are simple and tractable; therefore they are suitable as the starting point. In practice, basic grammars are developed and then rules applied until a design is reached that may be appropriate for the given project.
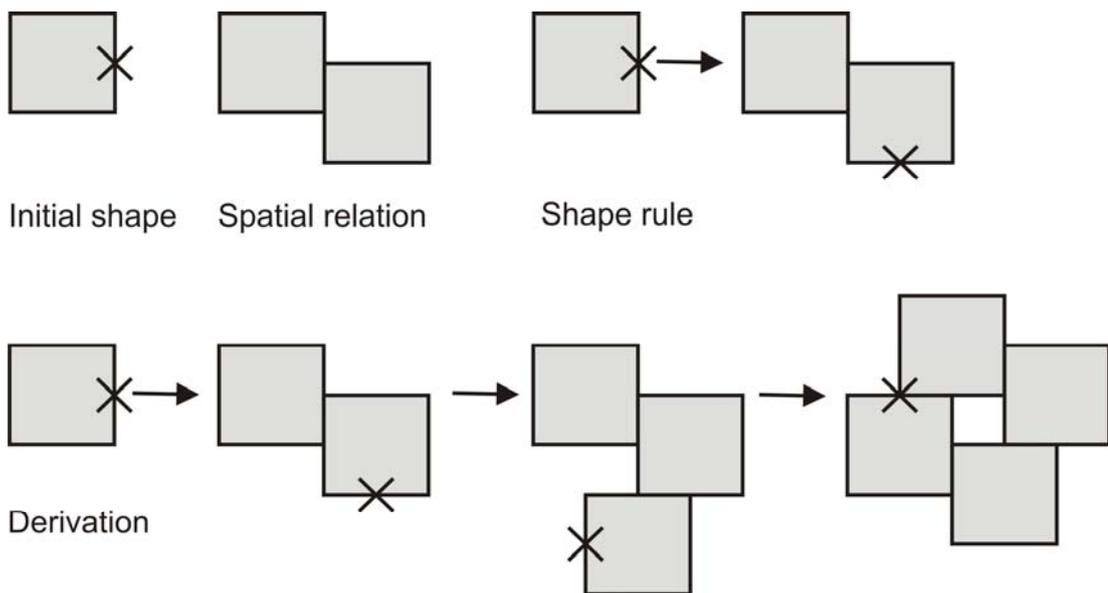
Figure 4- 2: An example of basic shape grammar

4.4.2.2 Parametric shape grammars

Stiny described parametric shape grammar (Figure 4- 3) in 1977 for the first time and it was used to construct traditional Chinese ice-ray lattice designs (Stiny, 1977), to generate the ground plans of Palladio's villas (Stiny & Mitchell, 1978a), to generate Hepplewhite-style chair-back designs (Knight, 1980), to generate Mughul gardens (Stiny & Mitchell, 1980), to construct members of rectangular architectural plans

(Earl, 1980), to analyse Wright's prairie houses (Koning & Eizenberg, 1981), to reproduce layout of Buffalo's bungalows (Downing & Flemming, 1981), to create layout of Japanese tearooms (Knight, 1981a) and to classify of Wren's churches (Buelinckx, 1993) and much more.

Parametric shape grammar are an extension of shape grammars, while they differs from basic shape grammar in that it contains shape rules defined in terms of labelled parameterised shapes instead of labelled shapes in basic shape grammars.
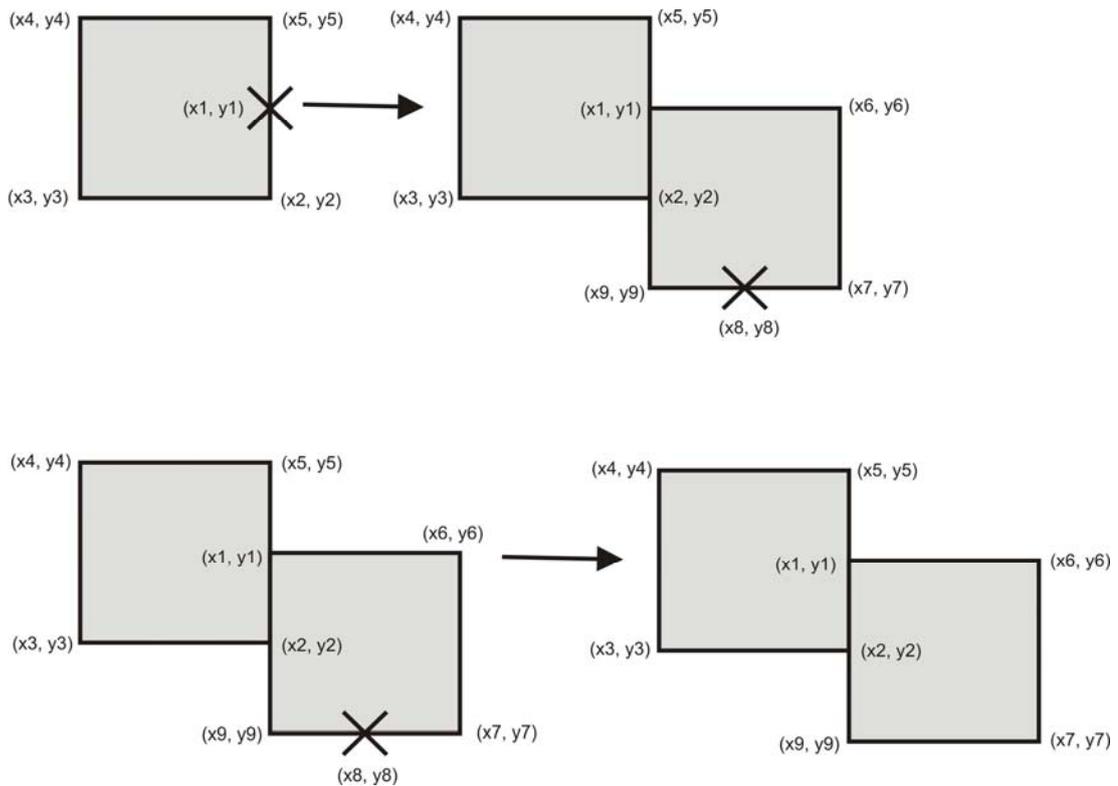
Figure 4- 3: An example of parametric shape grammar

4.4.2.3 Description grammars

Description shape grammars, which were invented by Stiny in 1981, explain the composition of designs and at the same time provide the basis for the description of these designs in other terms. Descriptions of designs specify in a finite way the relevant features and properties of designs determined according to some fixed criterion of interest. These description functions (Stiny, 1981) provide the link

between designs defined by shape grammars and descriptions defined by formal rule systems.

"From a line description of a design in terms of its constituent shapes, Stiny shows in "A note on the description of designs" (pp. 257 - 267) how functional and other meaningful descriptions may be derived (March, 1981a)". Designs in a language defined by a shape grammar are just shapes built up according to certain compositional rules. However other aspects of designs such as their function or meaning can be fixed by associating descriptions with them. These descriptions serve to extend designs understanding by connecting them with a complex of other ideas.

In brief, a description shape grammar has two main parts: (1) a shape grammar which specifies the rules given to compose the spatial elements in these designs, and, (2) a description function which specifies the rules given to describe these designs in other terms pertaining to, for example, purpose, function, and use, meaning, type, or form.

Description grammars (Stiny, 1981) are grammars that compute text or numerical descriptions of designs, for example, rather than spatial descriptions. A shape grammar and a description grammar can be linked so that shapes and descriptions of shapes are computed simultaneously. Descriptions of shapes might have to do with their meaning, function, aesthetics, geometry, and so on.

4.4.2.4 Parallel grammars

Parallel grammars were first proposed by Stiny (1981). Parallel grammars defined in multiple algebras and simultaneously compute different shape, text, or symbolic representations of designs (for example, plans, sections, and elevations together with verbal descriptions of them).

Stiny's early example of a parallel grammar consisted of a shape grammar and a description grammar (1981). The shape grammar generates simple, block-like structures. The description grammar generates non-spatial, symbolic descriptions of the components of these structures. A more complex example of a parallel grammar

was given recently by Andrew Li (2001). Li's parallel grammar is for traditional Chinese buildings. The grammar consists of sixteen different grammars. Some grammars generate visual representations of designs such as sections, elevations, and plans. Other grammars generate numerical or verbal descriptions of designs. All of the grammars run in parallel to generate, simultaneously, multiple views and multiple descriptions of buildings.

In brief, a parallel grammar is a network of two or more grammars that operate simultaneously. The networked grammars may be shape grammars or grammars of other kinds, for instance, grammars that compute with text or symbols. The rules of the grammars apply simultaneously to define parallel computations.

4.5   Summary

It was discussed that shape grammars are a well-established formalism for analysing and generating an existing body of work. They are also used to answer complexities of shape and shape computations. They are one of the earliest algorithmic systems for understanding designs directly through shapes, rather than indirectly through text or symbols. Different applications of shape grammars were mentioned too.

Through the time, shape grammars theory has advanced to answer a variety of design problems and now shape grammars are successfully used for analysing and describing existing designs, as well as for the creation of completely new designs. Here, the specific reasons behind choosing shape grammars for studying Persian mosques will be mentioned:

4.5.1   Characteristics of shape grammars

Over the past decades, shape grammars formalism has been successfully used to describe and analyse past or present designs, as it has some characteristics that make it suitable for analysing purposes: Firstly, shape grammars are spatial, rather than textual, symbolic or algorithms. Shape grammar is different from symbolic grammars as it transforms shapes in two-dimensions and three-dimensions different from symbolic grammar which transforms strings of symbols in one dimension only.

Secondly, shape grammars are both descriptive and generative. The rules of a shape grammar generate or compute designs and they themselves are descriptions of the forms of the generated designs. Thirdly, they can be decomposed and recomposed freely according to the needs and the judgments of designers and they allow emergence. "Emergence" is the ability to recognize and to operate on shapes that are not predefined in a grammar but are formed from any parts of shapes generated through rule applications. In shape grammars, the users have many choices of rules and ways to apply them in each step. And as a design is computed, there may be multiple choices that respond differently to conditions or goals. And finally, as it was discussed, shape grammars can be injected into all stages of design process: (1) before the synthesis of a design, as an advisor; (2) after the synthesis of the design, as a critic; (3) and during the synthesis of the design, as a generator.

4.5.2   *Shape grammars and categorisation of Persian mosques*

The only existing studies about Persian mosques are all descriptive and their terms are typically borrowed from common language, thereby creating a casual and sometimes intuitive terminology. As in a language, a meaning emerges from common use of language elements or terms that equally maintains an individual meaning. Thus existing studies about Persian mosques are all vague, subjective and highly experiential.

The first challenge of this research was to find a shared terminology to study these buildings. The unique characteristics of shape grammars, which were discussed here, convinced to use them in the present study. Shape grammar analysis creates subjective and dynamic classes, as they are based on spatial information of the Persian mosques. This chapter is the beginning of a flow in the study of Persian mosques from descriptions and words towards categorisation and classification of their plans by shape grammars.

Generally, classification is used to create order and stability for the communication of knowledge, but it should also have a dynamic structure. These are very important factors, as a classification has the risk of becoming stale and out of phase with time.

The analytic shape grammars have both of these qualities, as was discussed in the variety of shape grammar applications in this chapter.

Another advantage of using shape grammars for categorisation is that not only it analyses existing body of designs, but new designs can also emerge from it. In other words, it will create a structure that supports the need of separation between different groups of buildings, while it will link across borders when an agreed identity between buildings exists. It has been argued that classification may work as a boundary object (Star, 1989) in situations such as these to mediate and support negotiations around which similarities and differences can be articulated (Harvey & Chrisman, 1998). This interpretation of classification means that classes can be customised to the user requirements, but also have common identities.

Moreover, a classification should be able to identify and verify the identity of building plans, often as a part of data-production activity. It means that the meaning of the building should be reintroduced and be embedded in the classification. And shape grammars have been successfully used for this purpose before too.

Finally, from the user's point of view, it is not only important to be able to look into the intended meaning of a plan, but also into how it has been interpreted and how it can be reproduced. Obviously it is not enough to supply a classification together with a short written description, but rather to show as much as possible about what goes into separating one class from another, and shape grammar analysis have this quality as it has a very simple and clear structure.

All the criteria listed above are key to the present study and they should be met in order to make correct identification and interpretation of Persian mosque plans. And as it was discussed here, the existing literature has proven that shape grammars are the right method for doing so.

4.5.3   Shape grammars and Persian mosques

The basis of shape grammar is the idea of capturing the knowledge behind designs: Persian mosques in this case. This type of analysis and design generation tends towards using systems based on well-defined geometry and away from the intuitive processes. By using shape grammars, different Persian mosques can be understood in terms of their vocabularies of shapes and the spatial relations between them. Then, these vocabularies and spatial relations may be used to define a shape grammar for them which generate the language of Persian mosque designs. The designs in this language are syntactically alike, as their compositions are governed by the same spatial relations. In the analysis of existing designs such as Persian mosques, the defined spatial relations provide the foundation for an intelligible discussion of formal characteristic and structure of designs.

In chapter five, shape grammars formalism has been used to study Persian mosque plans.

Chapter 5: Shape Grammar Analysis

5.1   Introduction

As was mentioned in the previous chapter, shape grammar is a well established formalism for analysing a group of designs in order to reveal their complex design. It studies design directly through shapes rather than indirectly through texts or symbols.

The group of eighteen Persian mosque plans will be analysed in the terms of the visual characteristics of their plans by shape grammar. Although the result will be a prototype that can be used in the computational system, here it will be only used to find the common characteristics of Persian mosque plans while to sustain the wide variety that distinguishes each one of them. This pluralistic approach is carried out with more details, while at the same time being more precise, than conventional analyses which are limited to wide or vague categorisations. Furthermore, this study avoids the need of a chronological ordering and the search for an ideal type, by allowing various types to be generated and even explaining the ways in which these simple types are created.

In this chapter, a shape grammar is developed based on the case studies described. The process of developing this shape grammar is shown in Figure 5- 1 (Stiny, 1980a). First, the plans are studied in order to find simple recurring formal elements

from them, and the spatial relations of these elements are extracted form them. Then, the rules of shape grammars are introduced; however a sequence in which these shape rules can be applied to a given initial shape is introduced before that and finally, the Persian mosques' shape grammars will be presented.

Figure 5- 1: Stages of shape grammar development (Stiny, 1980a)

It should be mentioned that the prototypes are defined using basic shape grammar (Figure 5- 2).
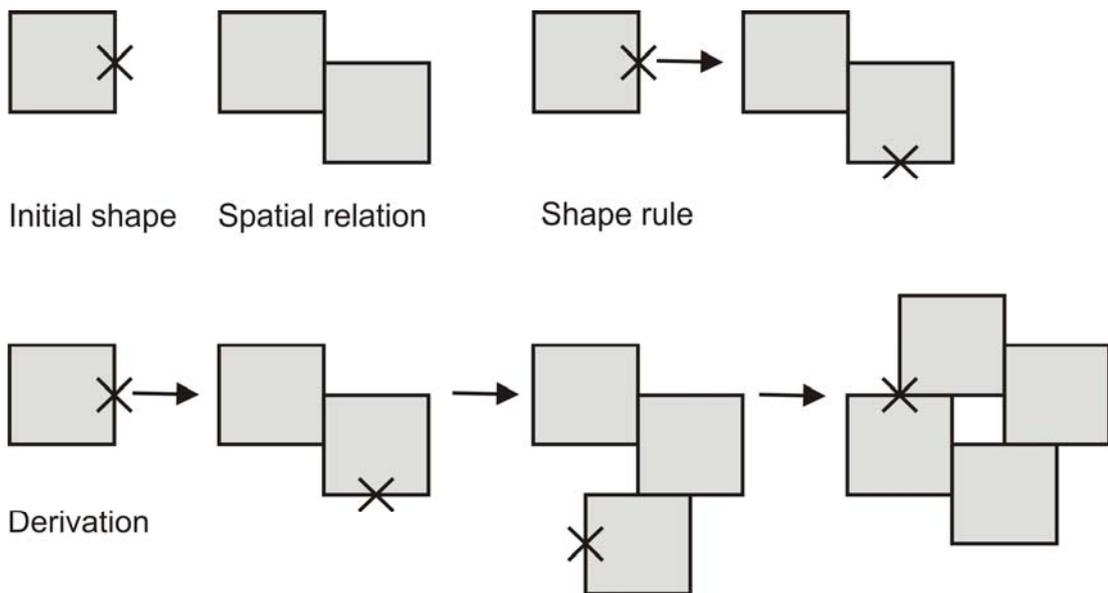
Figure 5- 2: An example of basic shape grammar

Finally in this chapter, the Persian mosque grammar is interpreted to understand what lies at the origin of some of the most quoted and least understood compositions of the mosques.

5.2   Case studies

The plan of Persian mosques (Figure 5- 3) will be analysed for the purpose of this research. This study is restricted to the analysis of the first floor plans of these one-storey mosques. Based on existing literature, their history and their plans were discussed in the third chapter. However, they will be studied by shape grammar for the first time here.
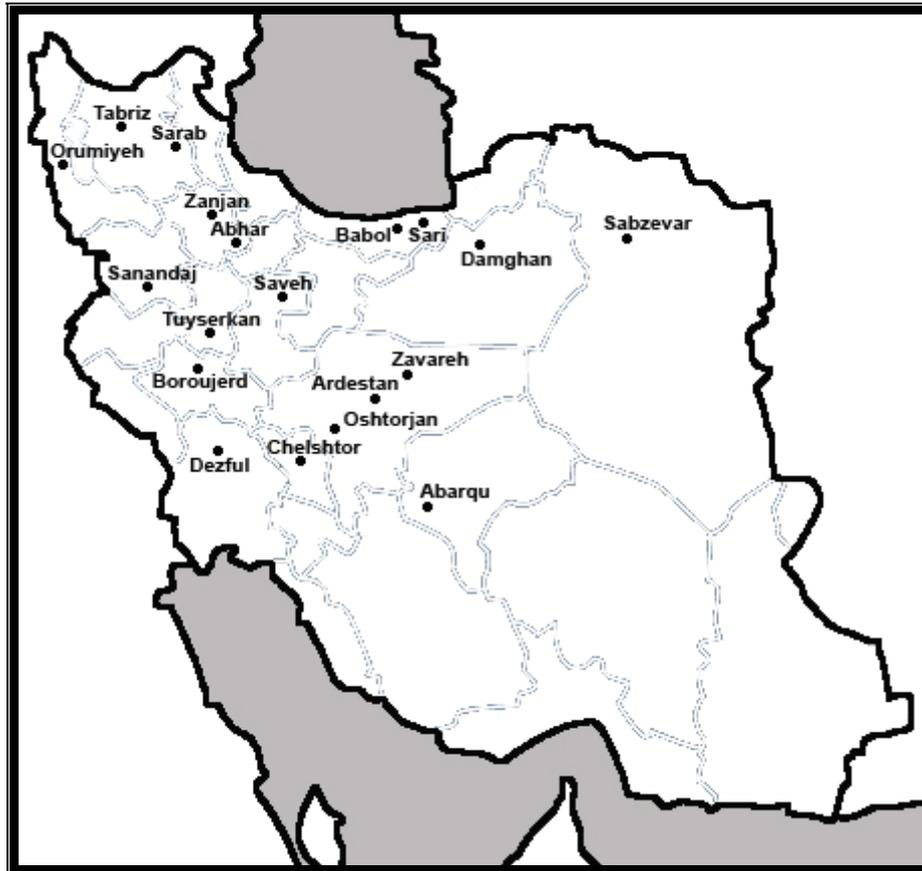
Figure 5- 3: Distribution of case studies in Iran

The spaces of the mosques which were explained in details in chapter three have been labelled with the following numbers:

1. Entrance   5. Gonbad-khaneh
2. Vestibule   6. Eivan
3. Courtyard   7. Mahtabi
4. Shabestan   8. Colonnade

9. Chamber   12. Vozu-khaneh

10. Lecture hall   13. Ghorfeh

11. Mausoleum   14. Prayer hall

5.2.1   *Circulation patterns of the Persian mosque plans*

The first step for analysing and categorising Persian mosque plans was to study their circulation patterns in order to find the relationship between spaces within the mosques.   Therefore, the circulation patterns of the plans have been studied and shown by diagrams here. In these diagrams, the units which represent spaces are of identical size and the numbers of these units are identical to the plan numbers. Moreover, the units are placed according to the actual location of the spaces in the plans. However, only important spaces are shown in the diagrams as it will allow flexibility in this stage.
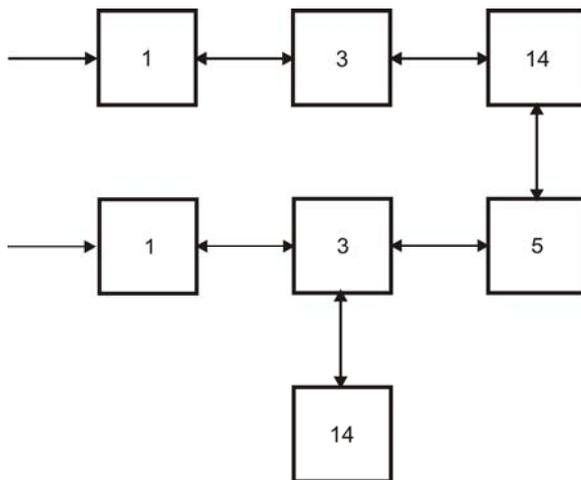
Abhar Congregational Mosque

Figure 5- 4: Circulation patterns in the Abhar congregational mosque plan

The circulation patterns of the Abhar congregational mosque shows that this mosque has two courtyards (space 3) separate from each other which are both connected to two different prayer halls (space 14).
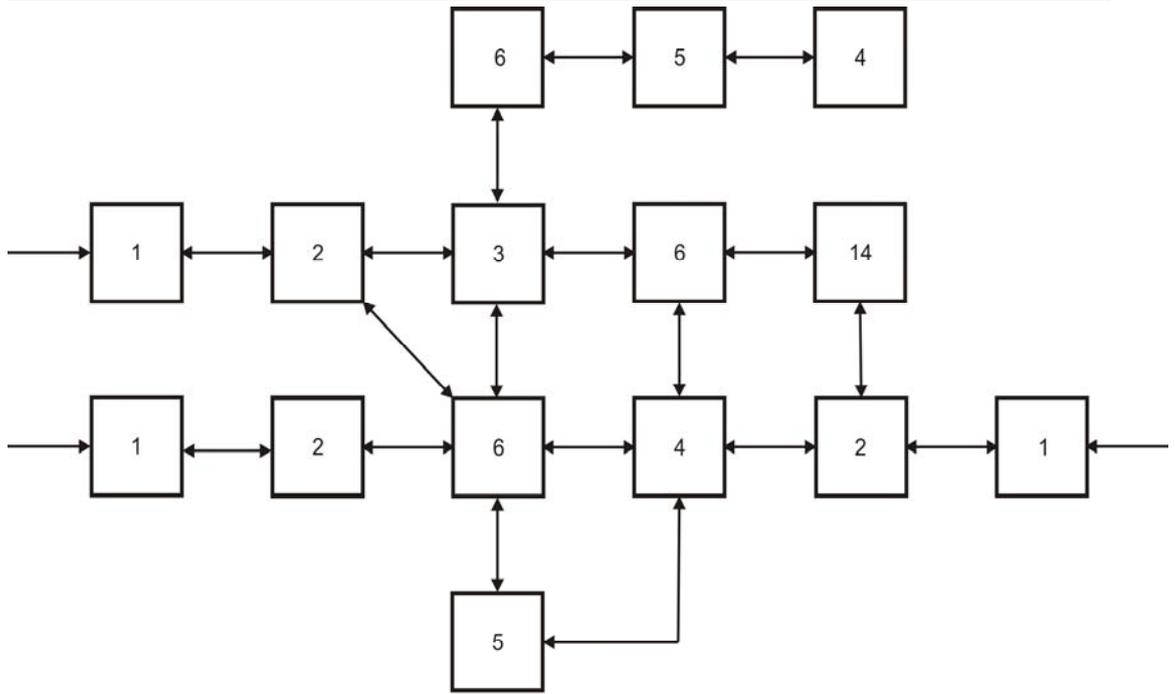
Ardestan Congregational Mosque

Figure 5- 5: Circulation patterns in Ardestan congregational mosque plan

The circulation patterns of the Ardestan congregational mosque (Figure 5- 5) reveal that the entrance (space 1) is located next to the vestibule (space 2). The same pattern in the plan of the Babol congregational mosque (Figure 5- 6) exists too. Moreover, in both of these plans, the eivan (space 6) and the gonbad-khaneh (space 5) are next to each other too. However, this is the case if the both of these spaces exist in the plan.
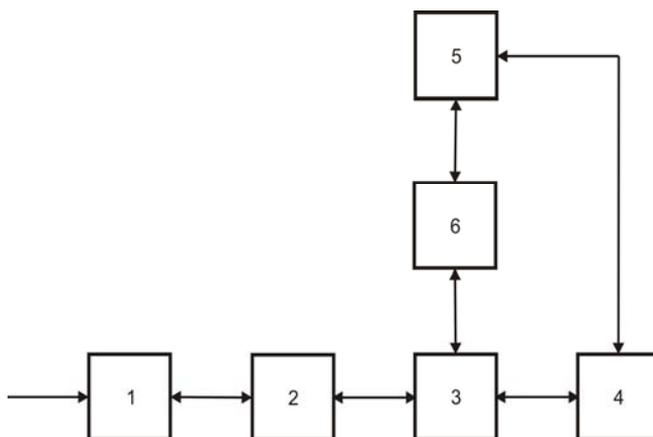
Babol Congregational Mosque

Figure 5- 6: Circulation patterns in Babol congregational mosque plan
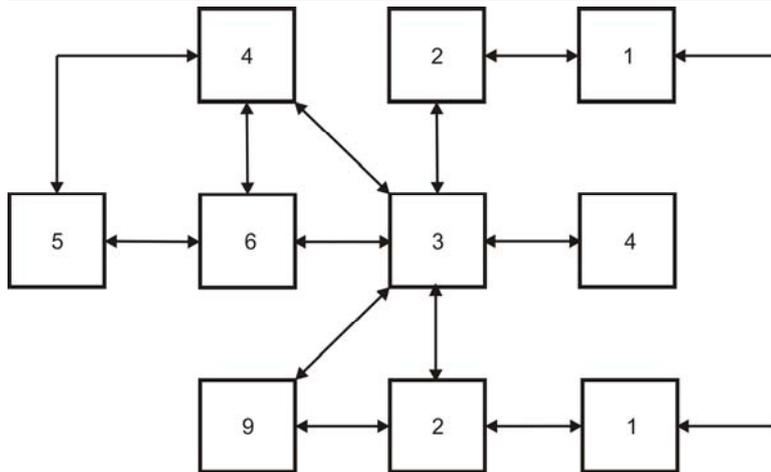
Boroujerd Congregational Mosque

Figure 5- 7: Circulation patterns in Boroujerd congregational mosque plan

In the plans of the Boroujerd and the Chaleshtor congregational mosques, these spaces (space 1-the entrance and space 2-the vestibule) are located next to each other.
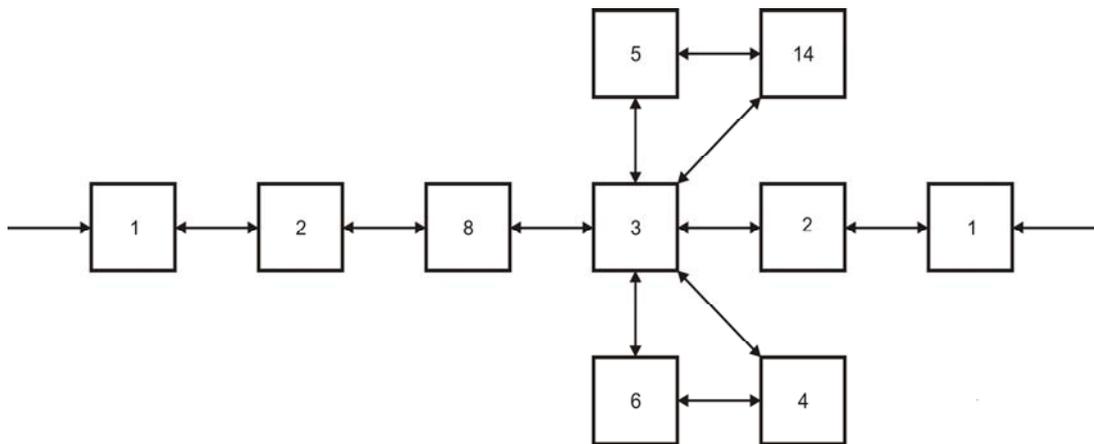
Chaleshtor Congregational Mosque

Figure 5- 8: Circulation patterns in Chaleshtor congregational mosque plan

Moreover, the diagrams reveal that both of these mosques have their courtyard in the middle of their plans with the most connectivity with other spaces within the mosques.
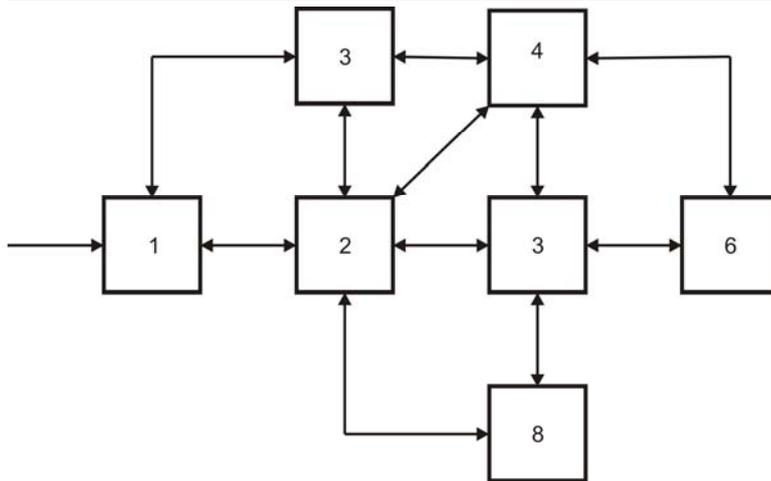
Damghan Congregational Mosque

Figure 5- 9: Circulation patterns in Damghan congregational mosque plan

In Figure 5- 9, the entrance and the vestibule are located one after another; however, this mosque does not have the space 5. The same can be said about the plan of the Dezful congregational mosques shown below in Figure 5- 10.
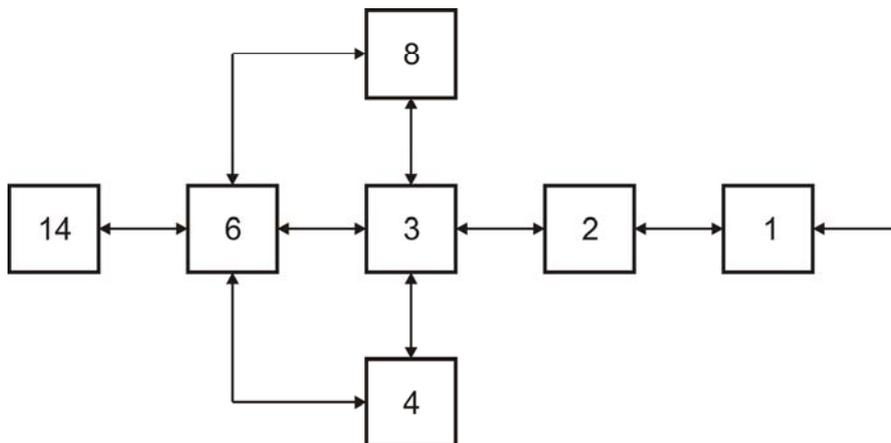
Dezful Congregational Mosque

Figure 5- 10: Circulation patterns in Dezful congregational mosque plan

In these mosques (Figure 5- 9 and Figure 5- 10), the importance of the courtyard (space 3) can be easily recognised, as both of them are located in the middle of the circulation with the most connections to the other spaces of the plans.

The plan of Oshtorjan congregational mosque (Figure 5- 11) does not have the vestibule (or space 2), but it shows a similar connection between space 5 (the eivan) and space 6 (the gonbad-khaneh). Plus, the courtyard again is in the middle of circulation with the most connectivity with other spaces in the plan.
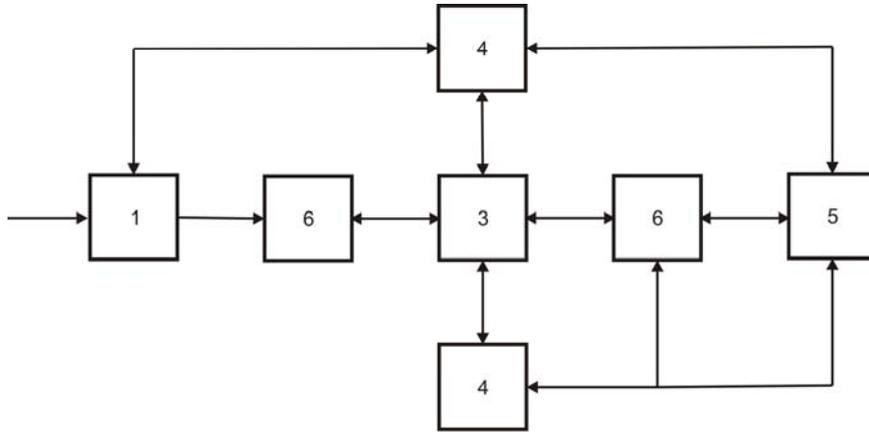
Oshtorjan Congregational Mosque

Figure 5- 11: Circulation patterns in Oshtorjan congregational mosque plan
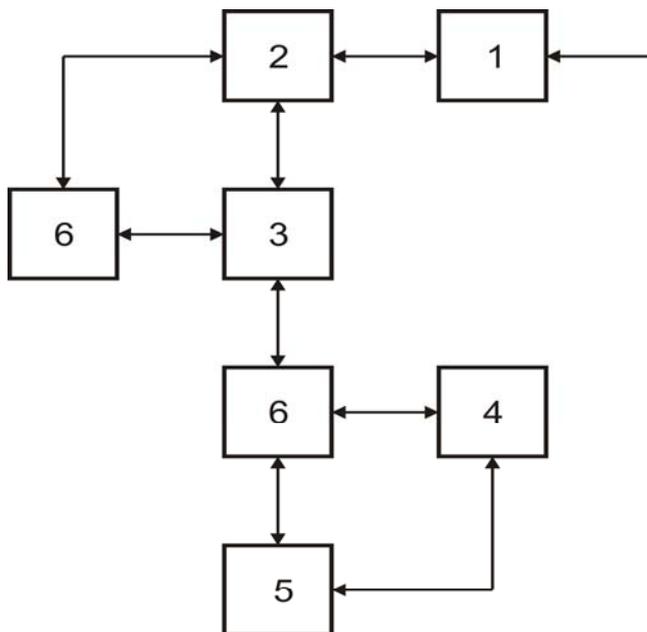
Sabzevar Congregational Mosque

Figure 5- 12: Circulation patterns in Sabzevar congregational mosque plan

In the plan of the Sabzevar congregational mosque (Figure 5- 12), the eivan (space 6) and the gonbad-khaneh (space 6) are connected and located next to each other.
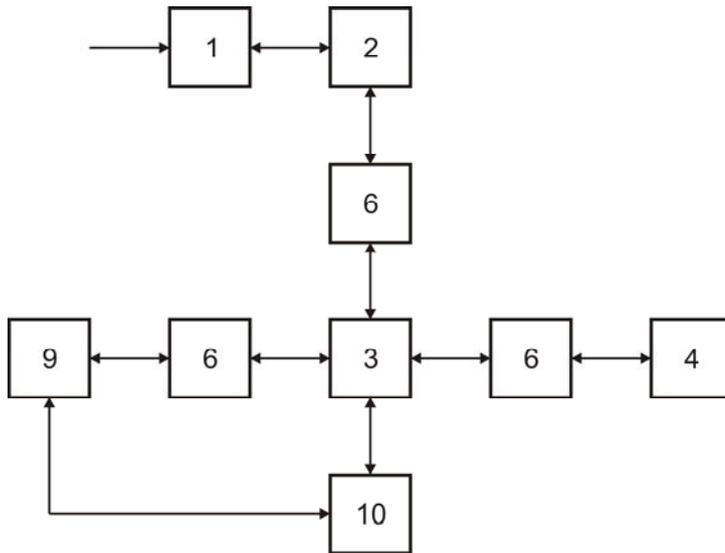
Sanandaj Congregational Mosque

Figure 5- 13: Circulation patterns in Sanandaj congregational mosque plan

The circulation patterns of the Sanandaj jame mosque (Figure 5- 13) show that its courtyard is its most important space with three eivans facing it.
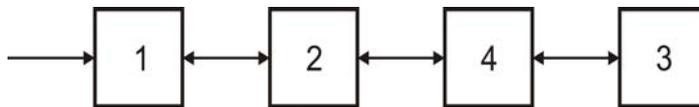
Sarab Congregational Mosque

Figure 5- 14: Circulation patterns in Sarab congregational mosque plan

However, the Sarab jame mosque has a very simple plan with only four spaces: (1) entrance or space 1, (2) vestibule or space 2, (3) courtyard or space 3 and (4) prayer hall or space 4.
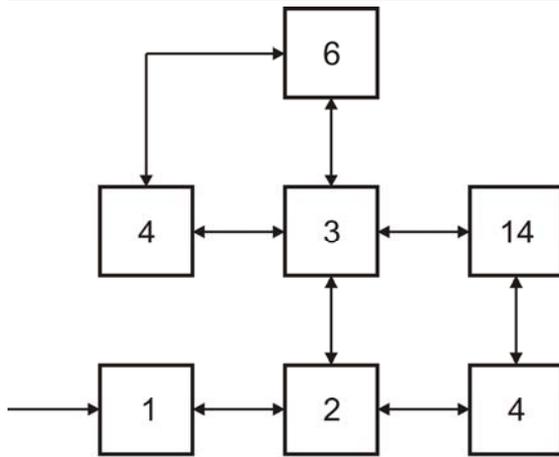
Sari Congregational Mosque

Figure 5- 15: Circulation patterns in Sari congregational mosque plan

In the plan of the Sari congregational mosque, the courtyard is located in the middle with the most connectivity to other spaces in the mosque.
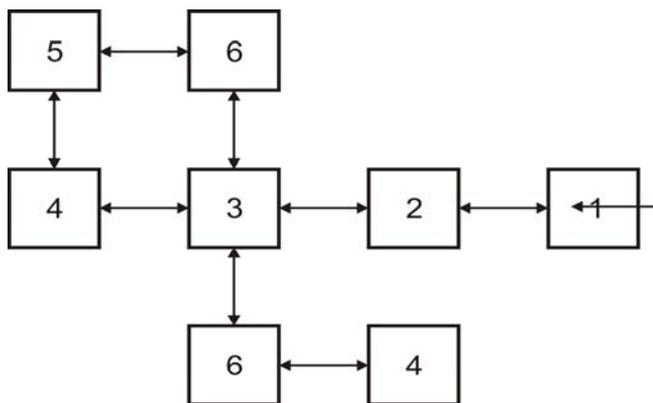
Saveh Congregational Mosque

Figure 5- 16: Circulation patterns in Saveh congregational mosque plan

The same observation can be made about the Saveh congregational mosque (Figure 5- 16), as the courtyard (space 3) is again in the middle of circulation with the most connectivity to other spaces. Moreover, the eivan (space 6) and the gonbad-khaneh (space 5) are located next to each other in this plan.
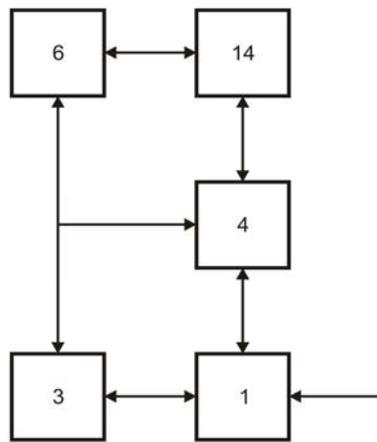
Tabriz Congregational Mosque

Figure 5- 17: Circulation patterns in Tabriz congregational mosque plan

Judging by the Tabriz circulation pattern (Figure 5- 17), it can be said that its plan has a vey simple structure with only five spaces.
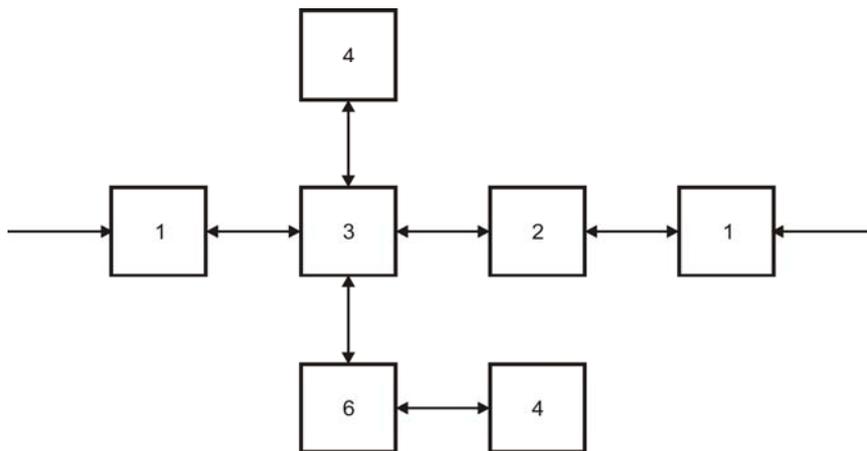
Tuyserkan Congregational Mosque

Figure 5- 18: Circulation patterns in Tuyserkan congregational mosque plan

The importance of the courtyard (space 3) in the plans of Persian mosques can once again be confirmed in the diagrams of the Tuyserkan congregational mosque (Figure 5- 18) and the Zanjan congregational mosque (Figure 5- 17).
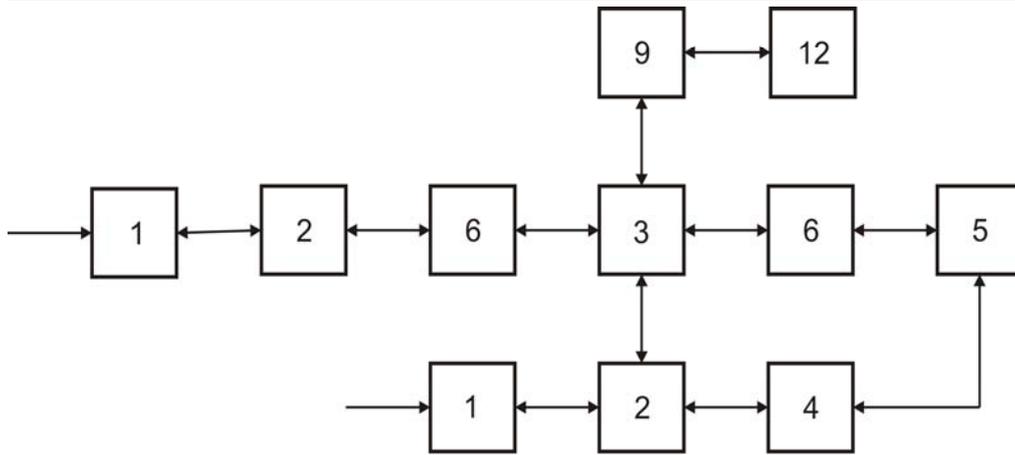
Zanjan Congregational Mosque

Figure 5- 19: Circulation patterns in Zanjan congregational mosque plan

In the diagrams of the Zanjan congregational mosque (Figure 5- 19) and the Zavareh congregational mosque (Figure 5- 20), the eivan (space 6) and the gonbad-khaneh (space 5) are connected; besides both of them have the entrance (space 1) next to the vestibule (space 2).
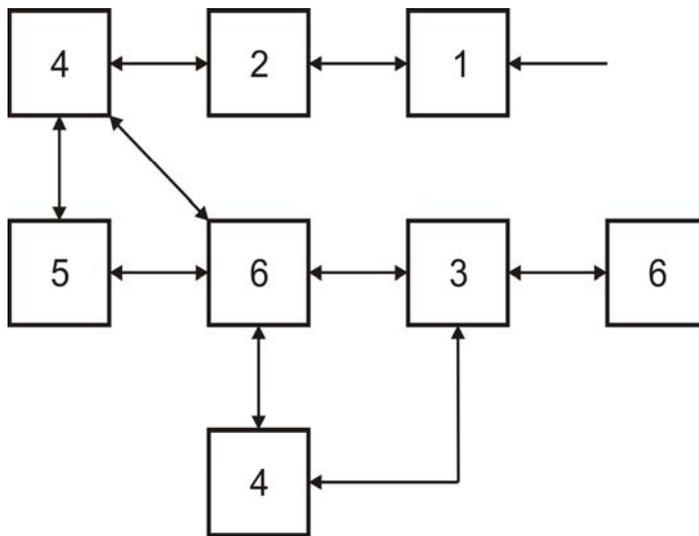
Zavareh Congregational Mosque

Figure 5- 20: Circulation patterns in Zavareh congregational mosque plan

These circulation diagrams reveal the relationship between the spaces. They show that the eivan (space 6) and the gonbad-khaneh (space 6) are located next to each

other in the plan. Moreover, the entrance (space 1) and the vestibule (space 2) have the similar relationship.

 Finally, they illustrate the organisation of the activities in each mosque, for example the courtyard is most of the time located in the middle of circulation with the most connectivity to the other spaces within the mosque.

These findings will be later used to define the shape grammar rules in this chapter. However before that, the characteristics of each spaces of the Persian mosque will be studied.

5.2.2   *Characteristics of the Persian mosque plans*

The study of the mosques' circulation patterns are very useful, but still not enough for defining the shape grammar rules, as more information about each individual space are needed in order to define the shape grammar rules. Therefore, the characteristics of the Persian mosque plans will be studied here.

The importance of the courtyard or space 3 was revealed in the study of the circulation patterns of the mosques. Here, the plans of the mosques are illustrated to show the position of the courtyard in the plans. The first group of the mosques (Figure 5- 21 and Figure 5- 22), which is the biggest group with eleven mosques, has their courtyard (shown with grey colour in the plans) in the middle of their plan with the most connectivity to other spaces.
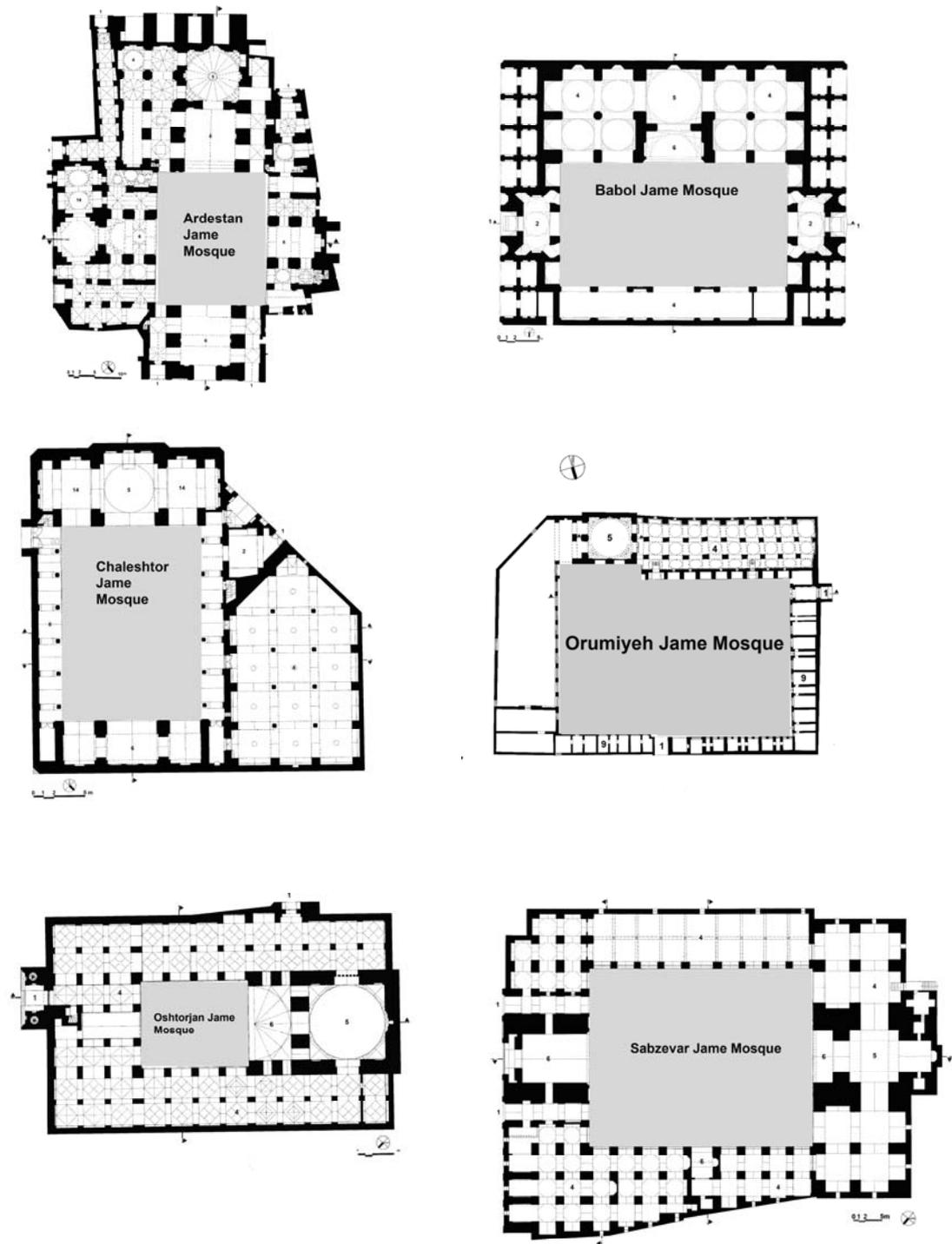
Figure 5- 21: The plans of the Persian Mosques with the courtyard (grey area) in the middle of the plan
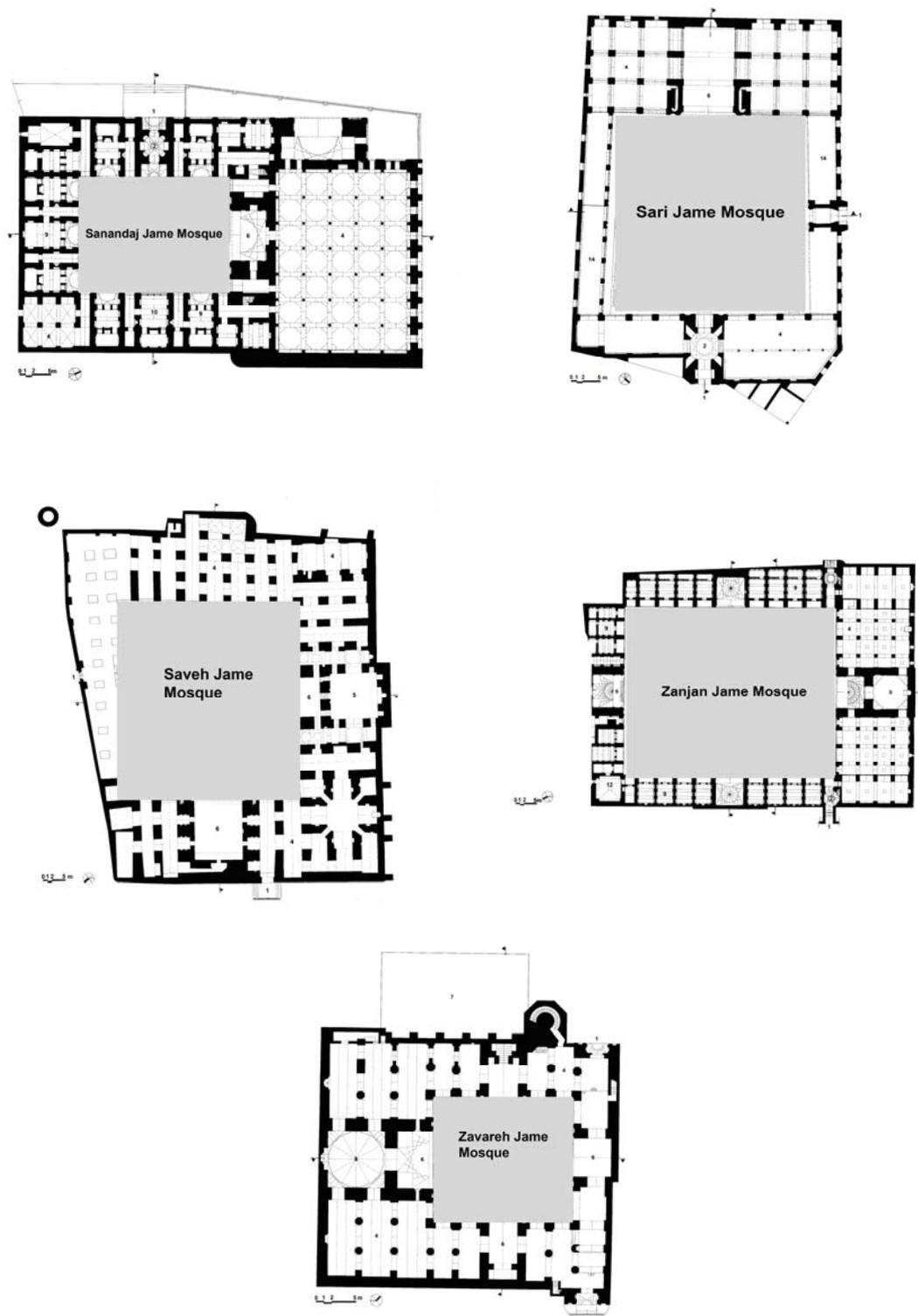
Figure 5- 22: The rest of the Persian Mosque plans with the courtyard (grey area) in the middle of the plan

However, two of the mosques (Figure 5- 23) have their courtyard (the grey area in the plan) in one side of their plan.
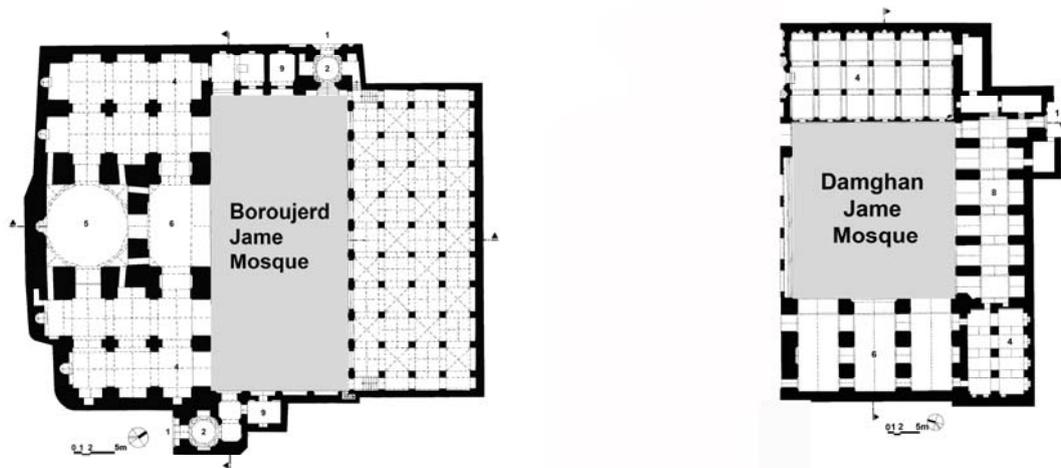
Figure 5- 23: The plans of two mosques with the courtyard (grey area) in one side of the plan

The plan of the Tuyserkan congregational mosque (Figure 5- 24) has instead two courtyards in two sides of the plan.
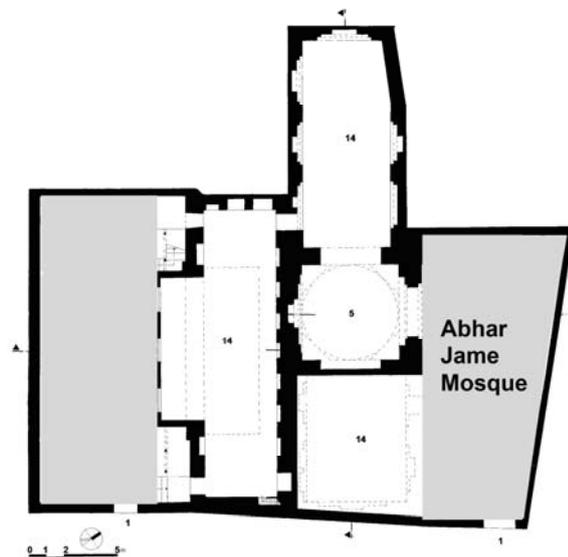
Figure 5- 24: The plan of the Tuyserkan Jame Mosque with two courtyards in two sides of the plan
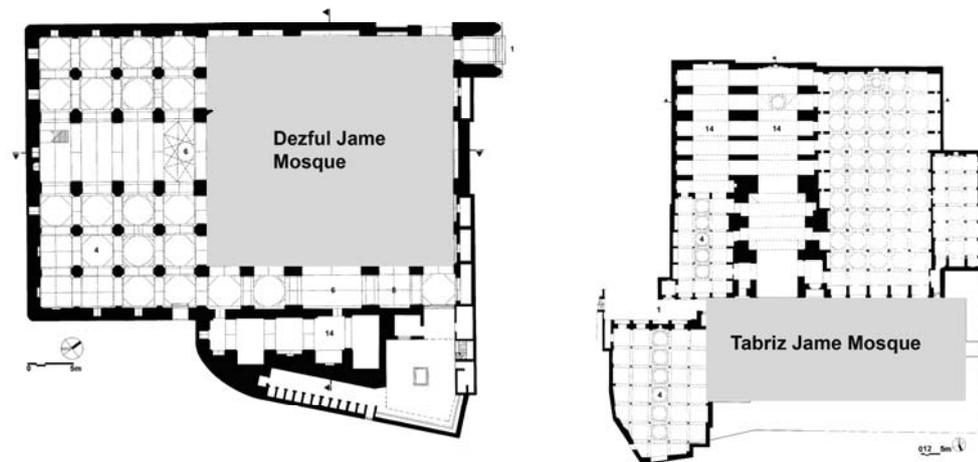
Figure 5- 25: The plans of the Dezful and the Tabriz Jame Mosque with the courtyard (grey area) in the corner of the plan

The next group (the Dezful and the Tabriz jame mosques shown in Figure 5- 25) has

only one courtyard but in the corner of the plan.
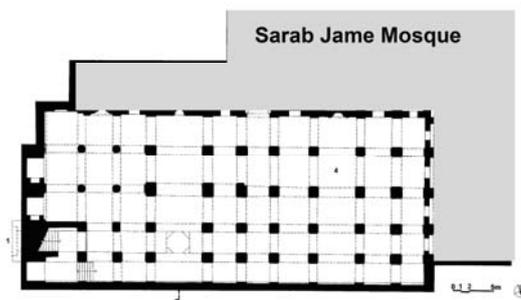
Figure 5- 26: The plan of the Sarab Jame Mosque with the prayer hall (white area) in the corner of the plan

The plan of the Sarab jame mosque has a unique style of its own, as in its plan, the

prayer hall (space 4 or white area) is located in the corner of the plan.

Another important characteristic of the mosque which is needed for the shape grammar rules is the location and the number of entrances in the mosques. In Figure 5- 27 to Figure 5- 30, the number of entrances in the plans of Persian mosques have been studied. Later in this chapter, this analysis will be used to introduce the stage four of Persian mosque shape grammars.
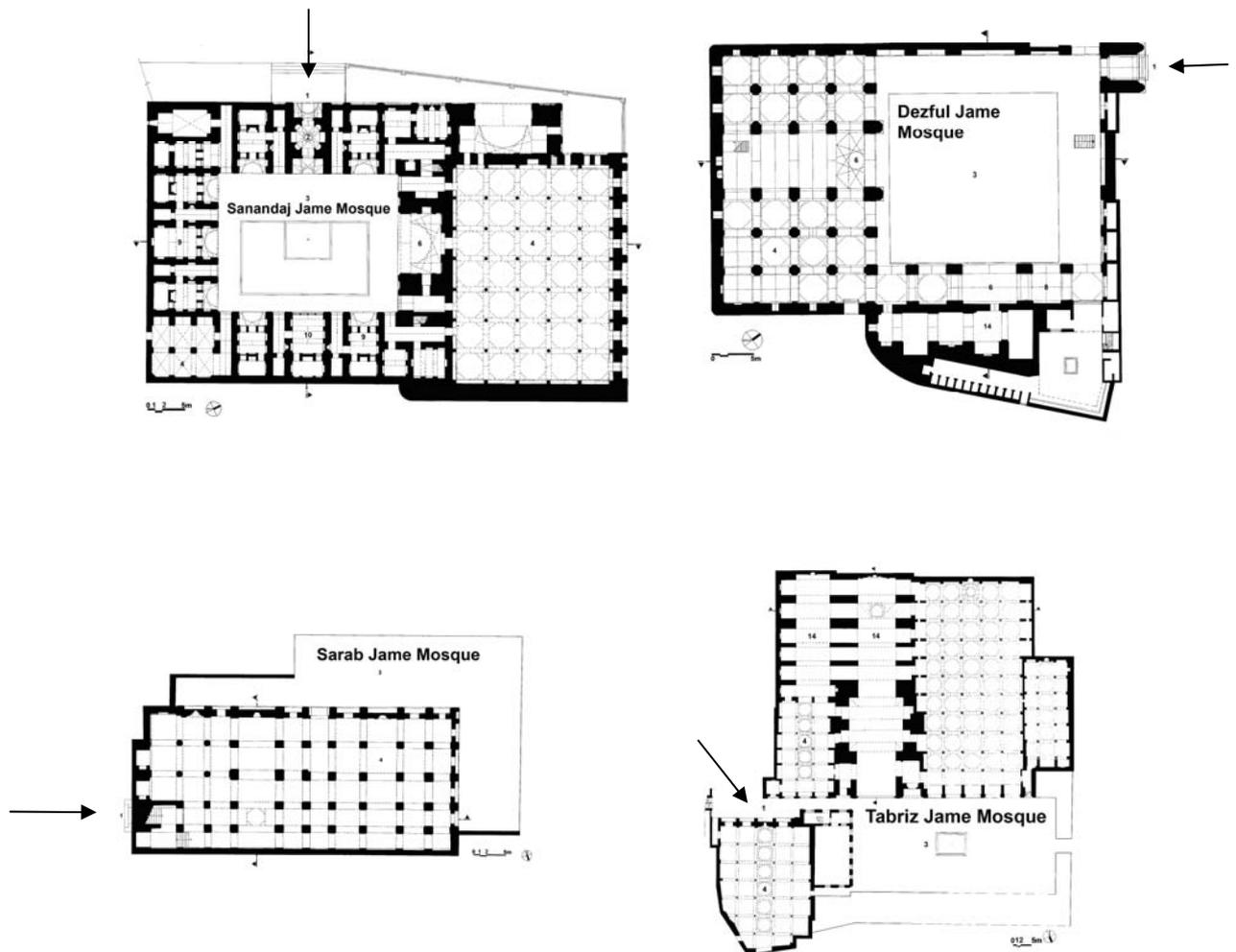
Figure 5- 27: This figure shows the plans of Persian mosques with one entrance (shown with the arrow).
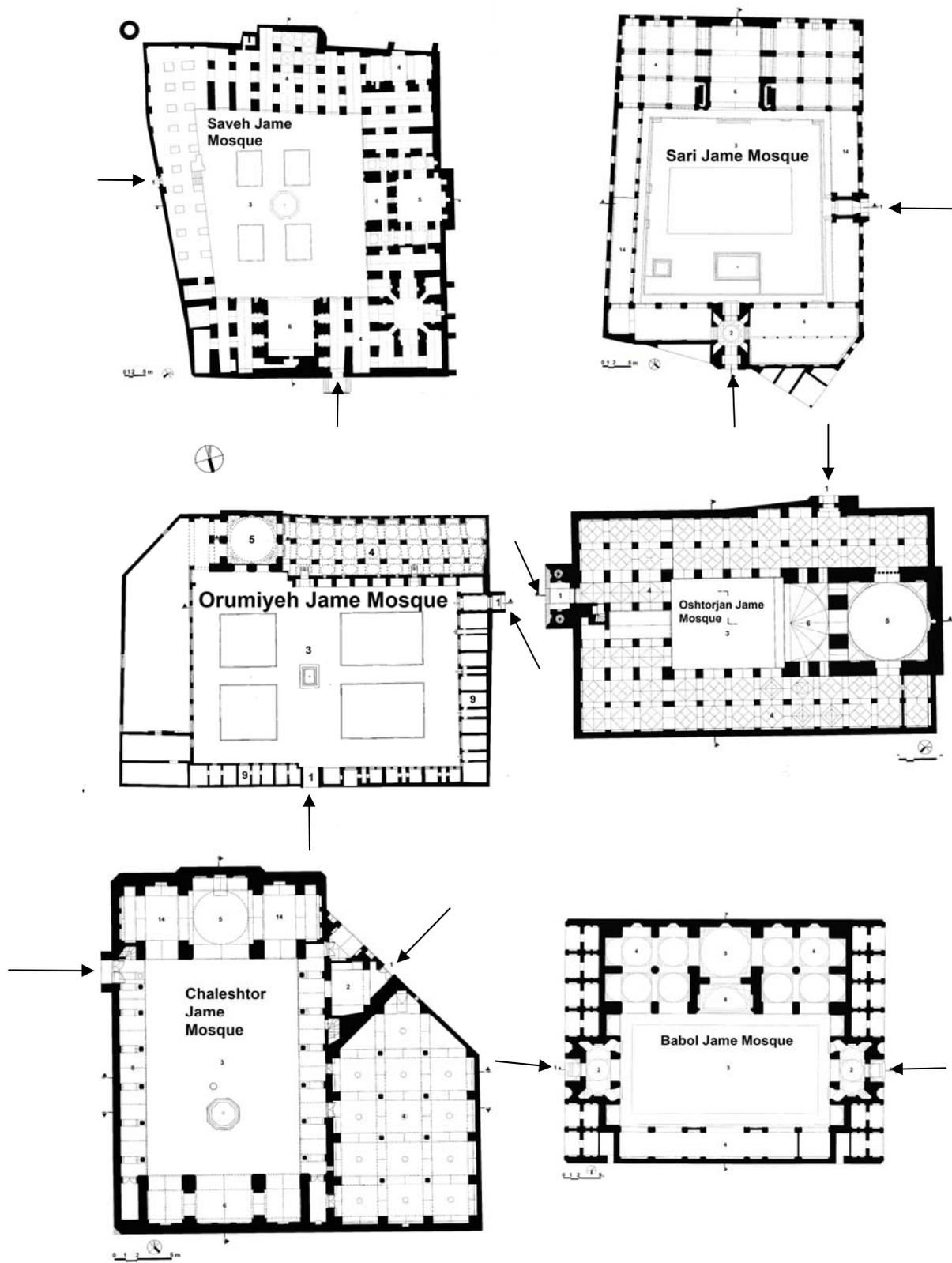
Figure 5- 28: The plans of Persian mosques with two entrances (shown with the arrows).
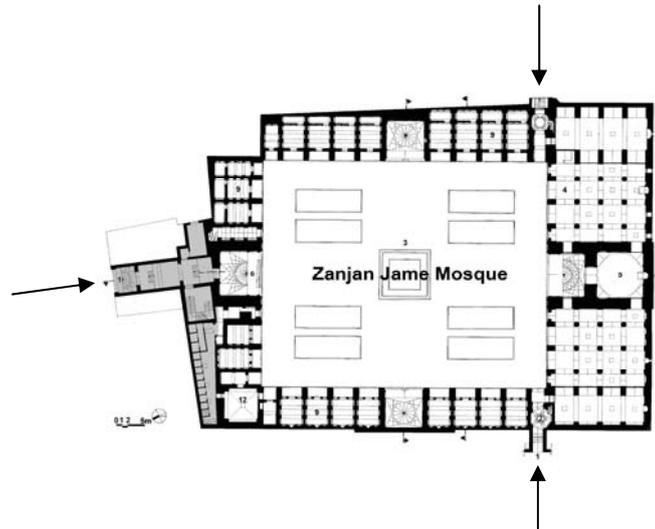
Figure 5- 29: The plan of the only mosque with three entrances (shown with the arrows).

Figure 5- 30: The plan of the only Persian mosque with more than three entrances (shown with the arrows).

Another important element in the plan of Persian mosque is the eivan (space 6) which was mentioned in the circulation patterns. Here, they will be studied in the plans. Figure 5- 31 shows the mosque plans which have the eivan in one side of their courtyard; the first group have one eivan in one side of their courtyard, while the second group has more than one courtyard but the eivans are all still located in one side of courtyard.

The plans with one eivan (space 6).

The plans with more than one eivan (space 6), but they are still located only in one

side of the courtyard.
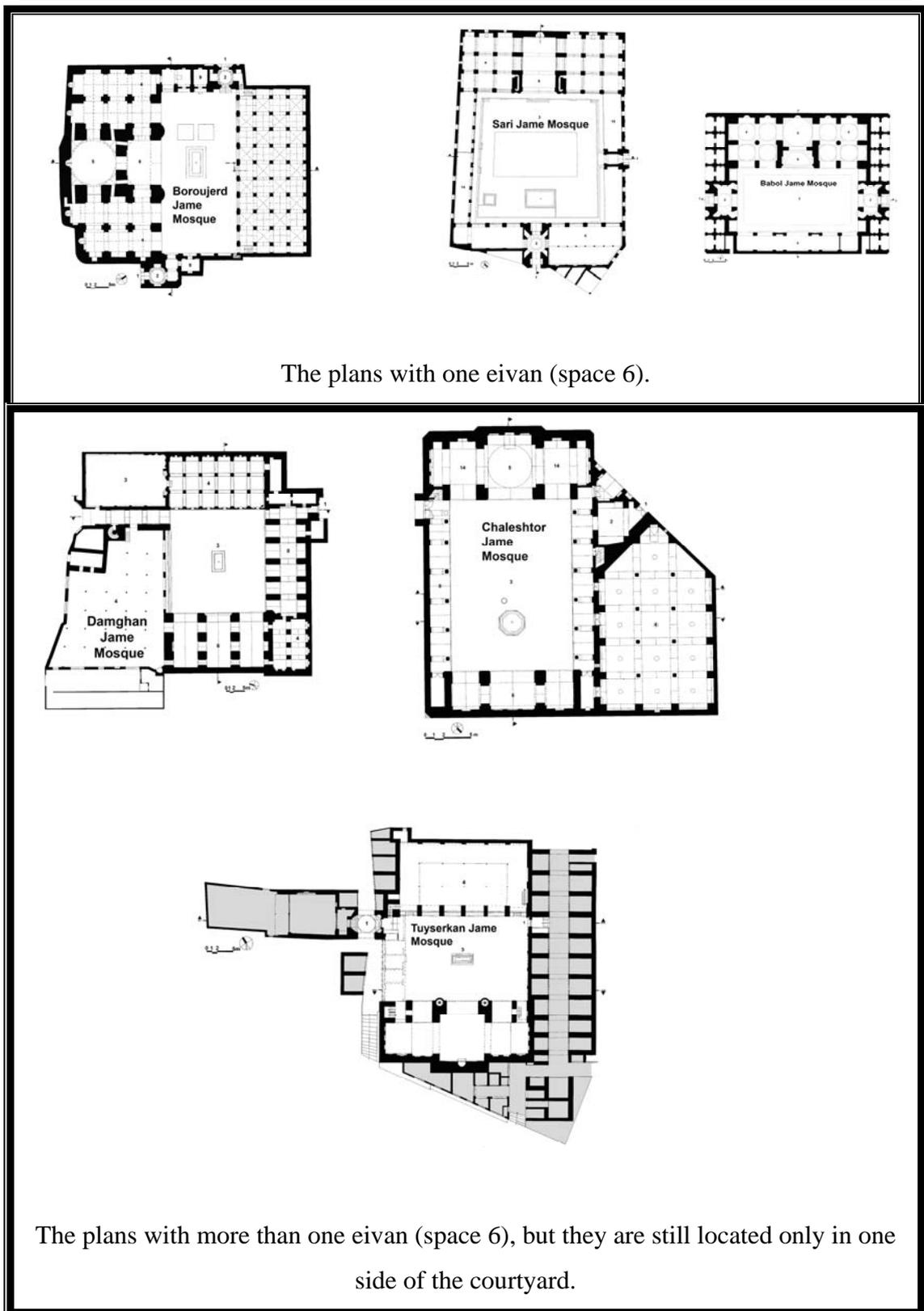
Figure 5- 31: The plans of Persian mosques with eivans only in one side of the courtyard. They can have one eivan or some facing the courtyard.

The plans in Figure 5- 32 have two eivans. In these plans, the location of eivans is an important feature that will be considered in the shape grammar rules later. Figure 5-33 is presenting the plan of Persian mosque with three eivans. The eivan and its location in the plans of Persian mosques will be discussed later in the stage three of Persian mosque shape grammars.
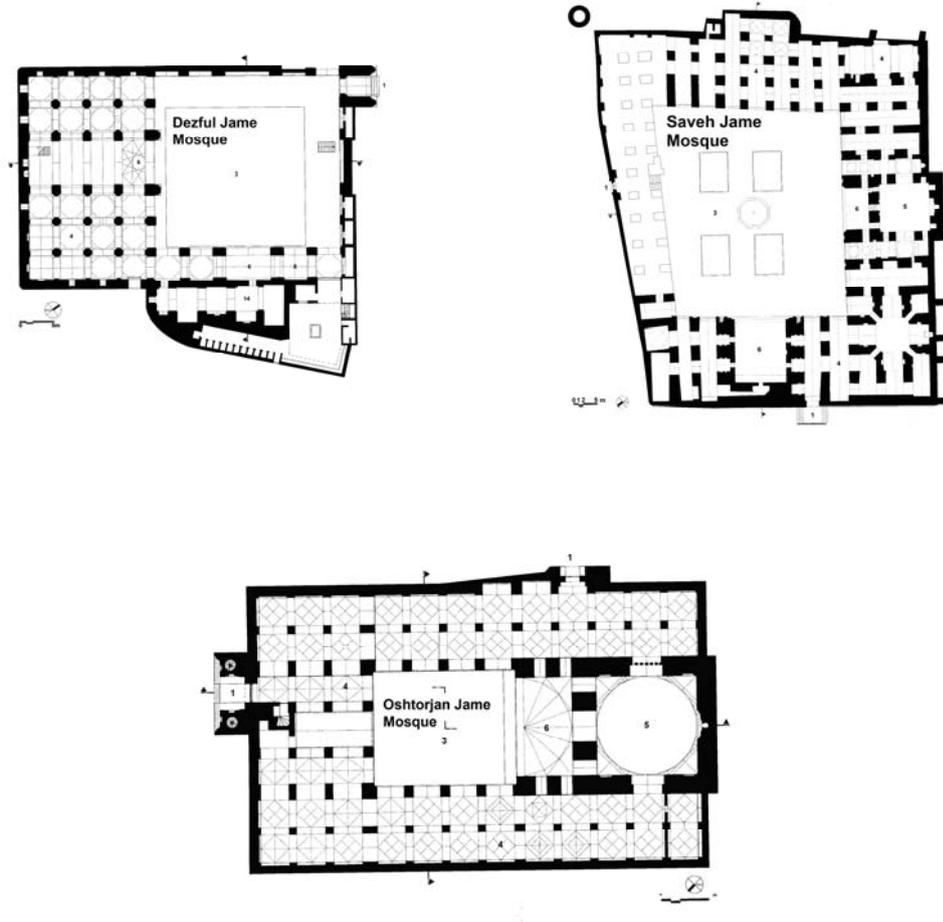
Figure 5- 32: The plans of Persian mosques with two eivans (space 6).
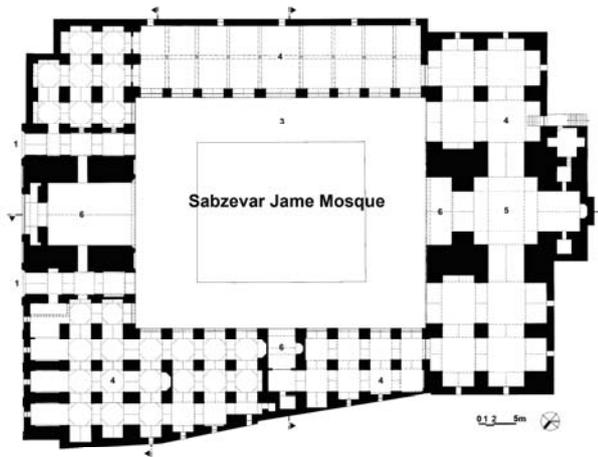
Figure 5- 33: the plan of the only mosque with three eivans: the Sabzevar Jame Mosque

The findings of the circulation patterns and the characteristics of the spaces studied here will be used to explain the spatial relations and to create a specified circulation pattern by shape rules. However, the size of these spaces is not the concern and will not be discussed.

5.2.3   *Spatial relations in the plans*

This stage of developing a grammar involves exploring the spatial relations between the spaces in the mosque plans. However, the recent extensions in the plans of the Persian mosques are not included in the analysis.

5.2.3.1 Qebleh

All of the mosques have a wall in their prayer halls which faces Mecca, in the Saudi Arabia. This direction is called qebleh and all prayers are directed towards it. This is a common rule in all the mosques regardless of any other factor in the mosque design.

5.2.3.2 Segregation of men and women

Often men and women prayers are kept separate in the mosque. This can be done by designing separate spaces for each group or by screens and curtains which are more

flexible and could be removed if needed. This is as well a common rule in all the mosque designs.

Because of the simplicity and the flexibility of using curtains and screens in the mosque, most of the time they are used for the segregation purposes. Therefore this common characteristic has been ignored in the shape grammar rules, as curtains and screens and so on are not architectural elements.

5.2.3.3 Courtyard

All of the case studies have at least one courtyard, an open space surrounded by walls with often a pool in the middle of it. The importance of the courtyard in the mosques was illustrated in this chapter. Courtyards are very common in the Persian architecture, especially in the house and the mosque designs.

In the mosque design, they are often used as an open space leading to the main space of the mosques. Mostly, they have strategically located after the entrance/vestibule, and before the prayer hall, in order to emphasise the façade and the process of entering the mosque for prayers. In the beginning of the chapter,

They are often used as a meeting point before entering the prayers. However in hot summer days, they can serve as prayer hall too. Moreover, its pool is mostly used for ablution before praying.

5.2.3.4 High Connectivity

The diagrams and the plans revealed the relationship between different spaces within the plans, or in other words, the space patterns of the plans. And a common pattern in these diagrams is the high connectivity between some single, independent spaces in the plans. These spaces with high connectivity are always found together in the plans.
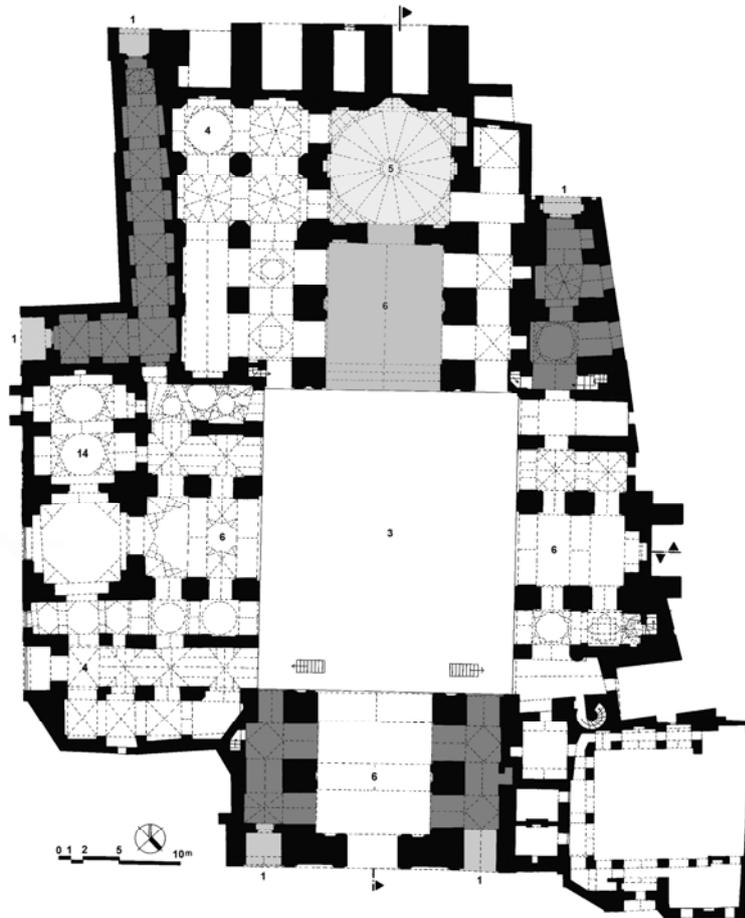
Figure 5- 34: An example of connectivity between space 1 (the entrance) and space 2 (the vestibule); and space 5 (the gonbad-khaneh) and space 6 (the eivan) in the plan of the Ardestan congregational mosque

There are two groups of such spaces in the mosque plans; (1) the eivan (space 6) and the gonbad-khaneh (space 5); and (2) the entrance (space 1) and the vestibule (space 2). These spaces are considered to have a very high connectivity with each other and if both of them appear in the plan, they will always be located next to each other. This high connectivity has been considered in the shape grammar rules and they have been located together. For example such a tendency can be seen between these spaces in the Ardestan congregational mosque's plan (Figure 5- 34).

5.3   *Shape grammar rules*

Developing a grammar includes finding simple reappearing elements in the plans, discovering the spatial relations between them, and introducing a sequence in which

these shape rules can be applied to an initial shape in order to produce various designs of mosque plans.

In the previous parts, the circulation patterns and the important characteristics of the mosques were discussed. Here, the sequence of applying the Persian shape grammar rules is introduced and later the shape grammar rules are defined.

5.3.1   *Sequences of shape grammar rules*

In the plans of Persian mosques, a vast number of plan variations can be seen; therefore a degree of simplicity in the organisation of the spaces is necessary in order to reach results. This organisation is the process of defining and grouping the spaces so that each one of them can be logically placed and effectively executed by shape grammar rules.

In order to do so, a certain sequence of applying the shape grammar rule has been defined. This sequence will allow the shape grammar rules to proceed in a way that allows the creation of a complete mosque plan.

Another way of simplifying the process of applying the shape grammar rules is grouping the spaces. This method has been introduced by the author in order to simplify the process of defining the shape grammar rules here. In order to do so, the high connectivity between some spaces in the Persian mosque plans, discovered in this chapter, has been used for this purpose.

The connectivity between eivan (space 6) and gonbad-khaneh (space 5) in one side; and entrance (space 1) and vestibule (space 2) on the other side have been considered as a block in the shape grammar rules.

These two factors, the sequence of shape grammar rules and the two blocks which represent the connectivity between spaces, have been shown in Figure 5- 35.
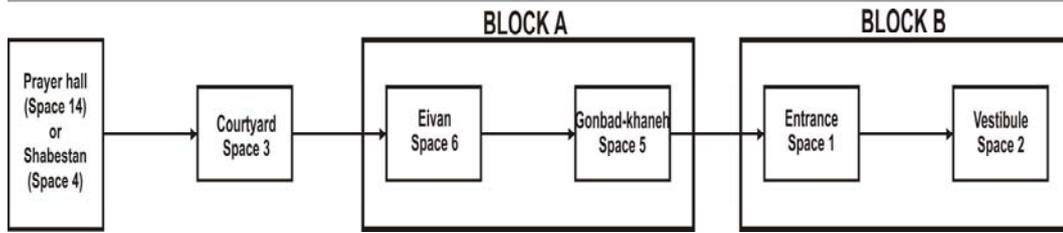
Figure 5- 35: Sequence of applying shape grammar rules

5.3.2 *Shape grammar rules*

In this part, a first attempt is made to produce Persian mosque grammar by shape grammar rules. These rules that generate mosque plans are specified here.

It should be mentioned that the shape grammar rules are identified by numbers and letters; the first number shows the number of the stage and the letter represents the sublevel (or blocks) within the stages and the last number of the shape grammar rule indicates the number of the rule in each stage. For example, the rule 15 is the 5th shape rule in the stage 1 and the rule 2A5 is the 5th rule in the stage 2A.

The plans are generated in five stages which include two blocks, block A (or eivan – space 6 and gonbad-khaneh – space 5), and block B (or entrance – space 1 and vestibule – space 2). These blocks represent the high connectivity discussed earlier in this chapter between the eivan and the gonbad-khaneh (block A) and the entrance and the vestibule (block B). The shape grammar starts with the initial shape that is prayer hall in general (space 14) or shabestan (space 4) here and then shape rules will apply on it. The stages afterward are according to the following sequence:

(1)   The courtyard or space 3 definition;

(2)   The eivan or space 6 definition (part one of block A);

(3)   The gonbad-khaneh or space 5 definition (part two of block A);

(4)   The entrance or space 1 definition (part one of block B); and

(5)   The vestibule or space 2 definition (part two of block B).

In this process, simple mosque plan layouts or prototypes are produced and in order to produce bigger mosques with more than one courtyard, the rules have to be reapplied again.

The prototypes are defined with the unit size which does not represent the real size of the spaces. During this process, plan layouts are generated with respect to the relationship between spaces and the plan circulations.

The initial shape from which all plans are generated by the sequential and recursive application of the rules is the shabestan (space 4) or prayer hall (space 14). Shabestan is a hypostyle prayer hall in a mosque which is covered with circular roof. Therefore, shabestan (space 4) is more specific term for prayer hall (space 14). In this analysis, as both of these spaces have one function, they are considered as one space in this analysis.

5.3.2.1 Stage 1

The most important feature of the Persian mosque plans is the shabestan (space 4), or in general term prayer hall (space 14), and the location of courtyard in relation with it. Therefore, this relationship forms the first stage of this shape grammar and the plans are constructed based on this relationship. The shape rules defined for the layout of the ground plan of Persian mosques is shown in Figure 5- 36.

Based on these eight rules, the main layouts of eight plan types have been produced below. However, in these rules the courtyard can be located at any side as there is no symbol in these rules.
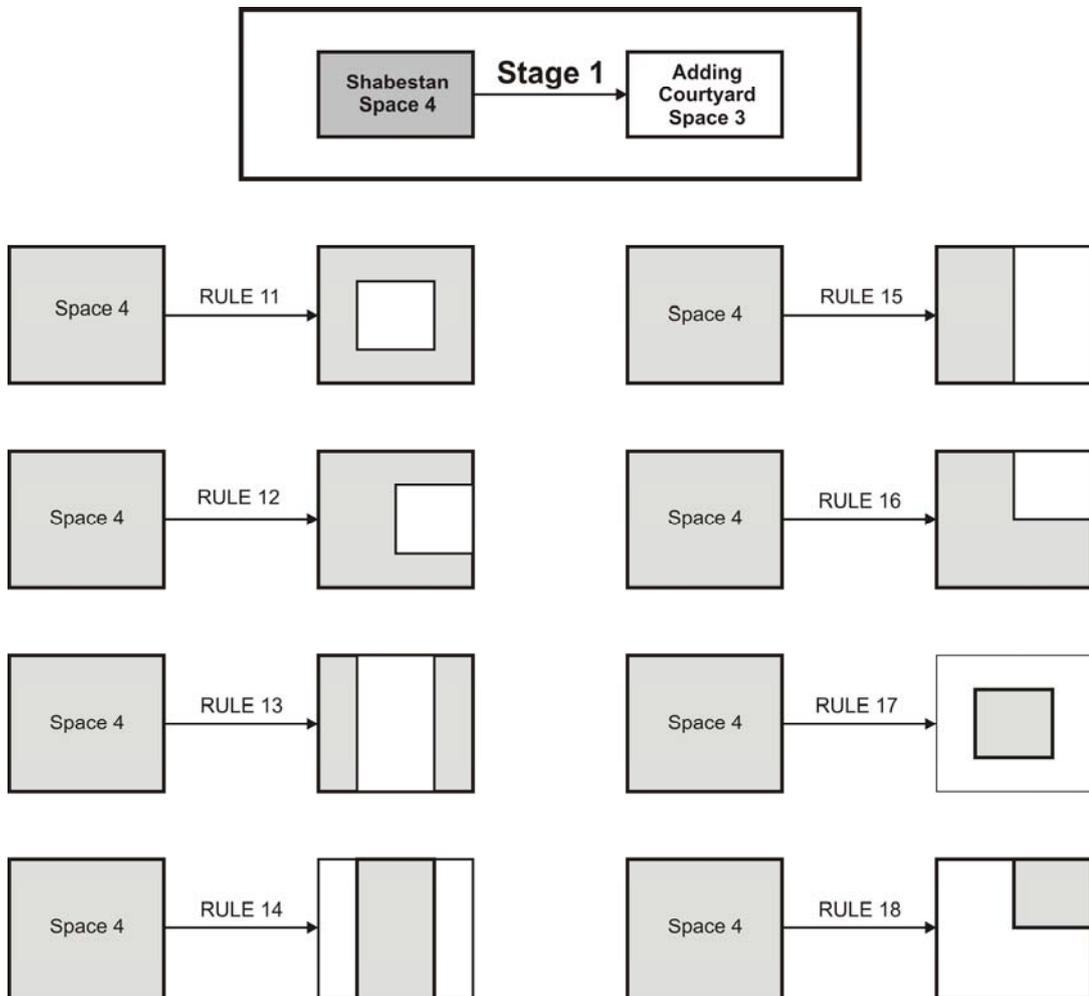
Figure 5- 36: First stage of generation of Persian mosque plans. This stage starts with the space 4 or initial shape and then space 3 or courtyard is added to.

5.3.2.2 Stage 2

The second stage has two parts. In the first part, the number of sides that eivan would be added is decided upon shown in Figure 5- 37. In this stage, omitting symbols help the process to be flexible in relation to the exact locations of eivans in the mosque.
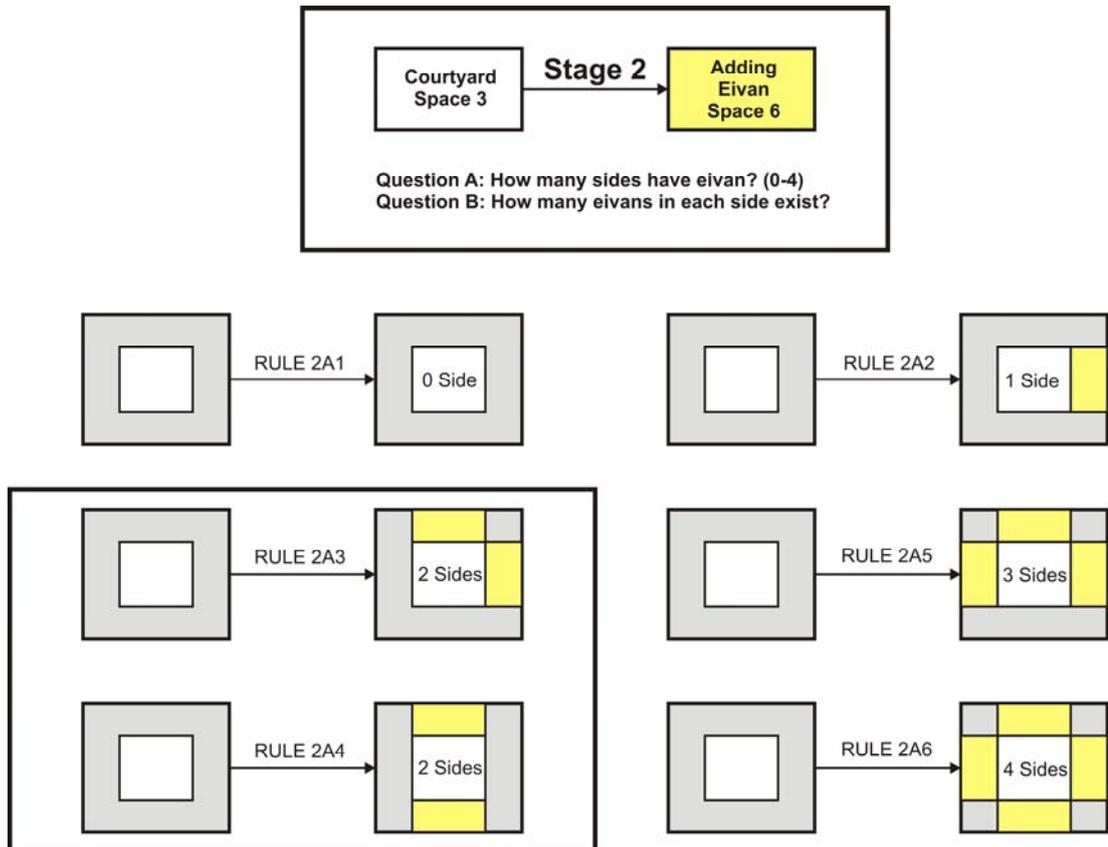
Figure 5- 37: In the first part of stage two, the number of the sides that eivan is needed is decided upon.

Next part of the stage two focuses on the number of eivans that should be added in each side shown in Figure 5- 38.

These numbers can be different in each side. However, most of the time a mosque has the same number of eivans in the sides facing each other and often a mosque has the same number of eivans in all the sides.

The eivans can have different sizes in a plan, however, in this case, most of the time the middle eivan is bigger and has higher ceiling. This eivan is often located toward the direction of Mecca.
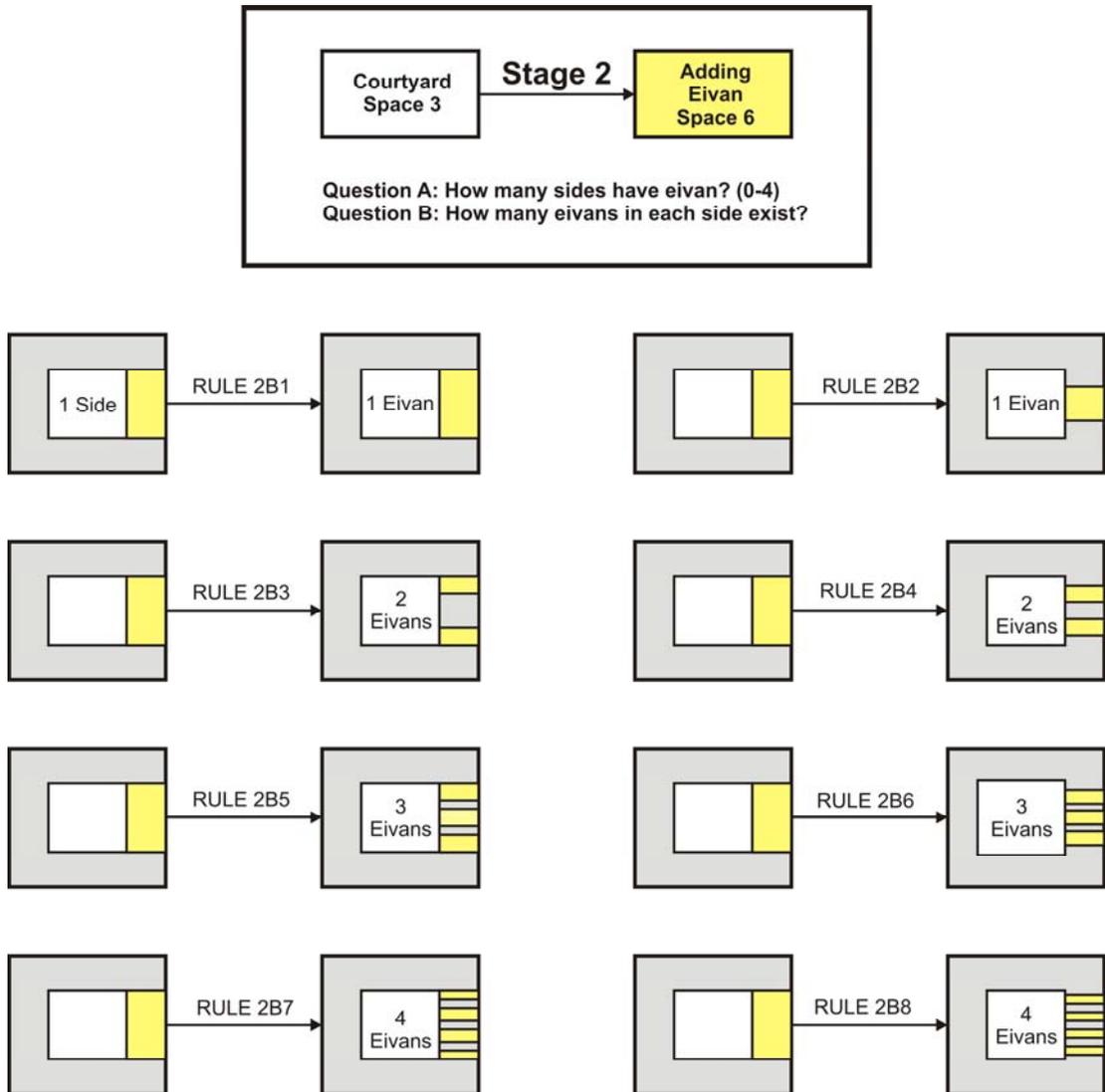
Figure 5- 38: In the second part of stage two, number of eivans in each side is the main question. The number and the size of eivans can be different in the mosques.

5.3.2.3 Stage 3

As it was mentioned before, eivan (space 6) and gonbad-khaneh (space 5) have high connectivity and if both of them appear in the plan, they are located next to each other in the Persian mosques. Therefore, gonbad-khaneh in this stage is located next to eivan (Figure 5- 39).

However, there are mosques which do not have any gonbad-khaneh or an eivan, so these possibilities have been considered in rule 31 and rule 33. In the rule 31, the plan will have no gonbad-khaneh and with rule 33, it will have only gonbad-khaneh.
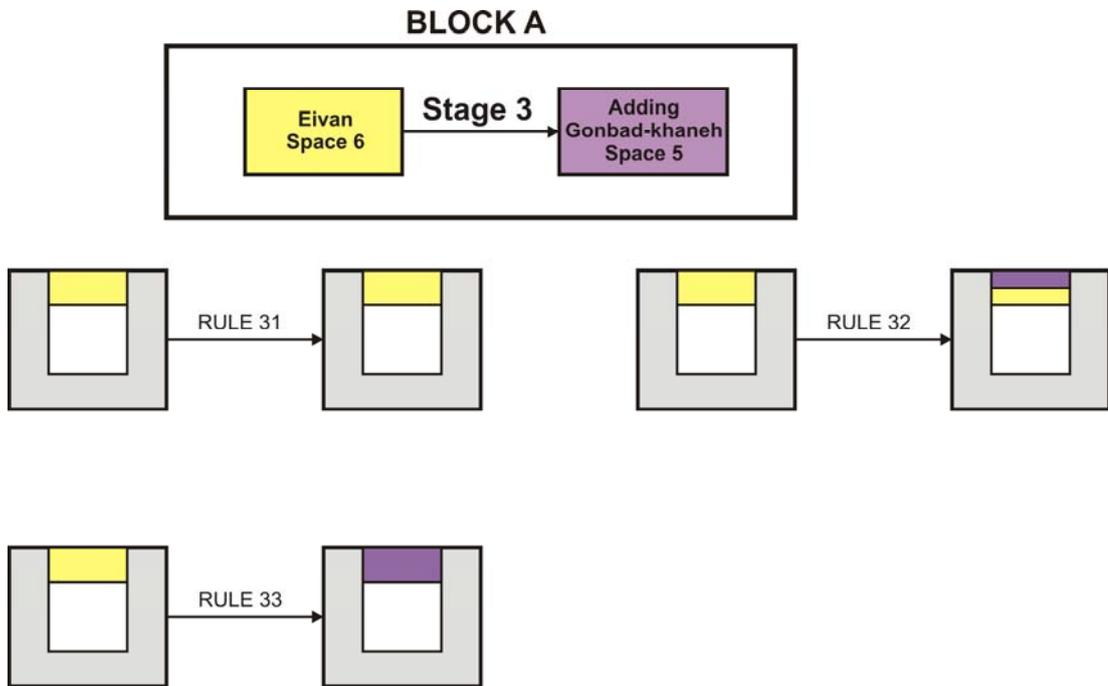
Figure 5- 39: In stage three, gonbad-khaneh is located next to eivan, however there is a possibility of having no gonbad-khaneh or only gonbad-khaneh.

5.3.2.4 Stage 4

Stage four consists of two groups of shape rules. These rules have been clarified in Figure 5- 40 to Figure 5- 43. In the first figure (Figure 5- 40), the shape rules show which sides have access to outside. In theory, there is a possibility of having one to four sides for entry. However, this is influenced by the reality of the plan location.

The next group of stage four rules (Figure 5- 41 to Figure 5- 43) define the location of entrances. These rules specify the exact location and the number of entrances in the plan. But as the exact location of the entrance is forced by the site, the entrance can be located in any edge and next to any space and there can be countless possibilities in theory. Most of the time, the mosques have one entrance, but in general two separate entrances for men and women are preferred number of entrances for the design of small size plans. It can be said that if the site plan allows it, two entrances are ideal for the plan of one-courtyard mosques.

These shape grammar rules try to specify the exact number and the location of each entrance. However in reality, they are mostly influenced by the constraints of location and site.
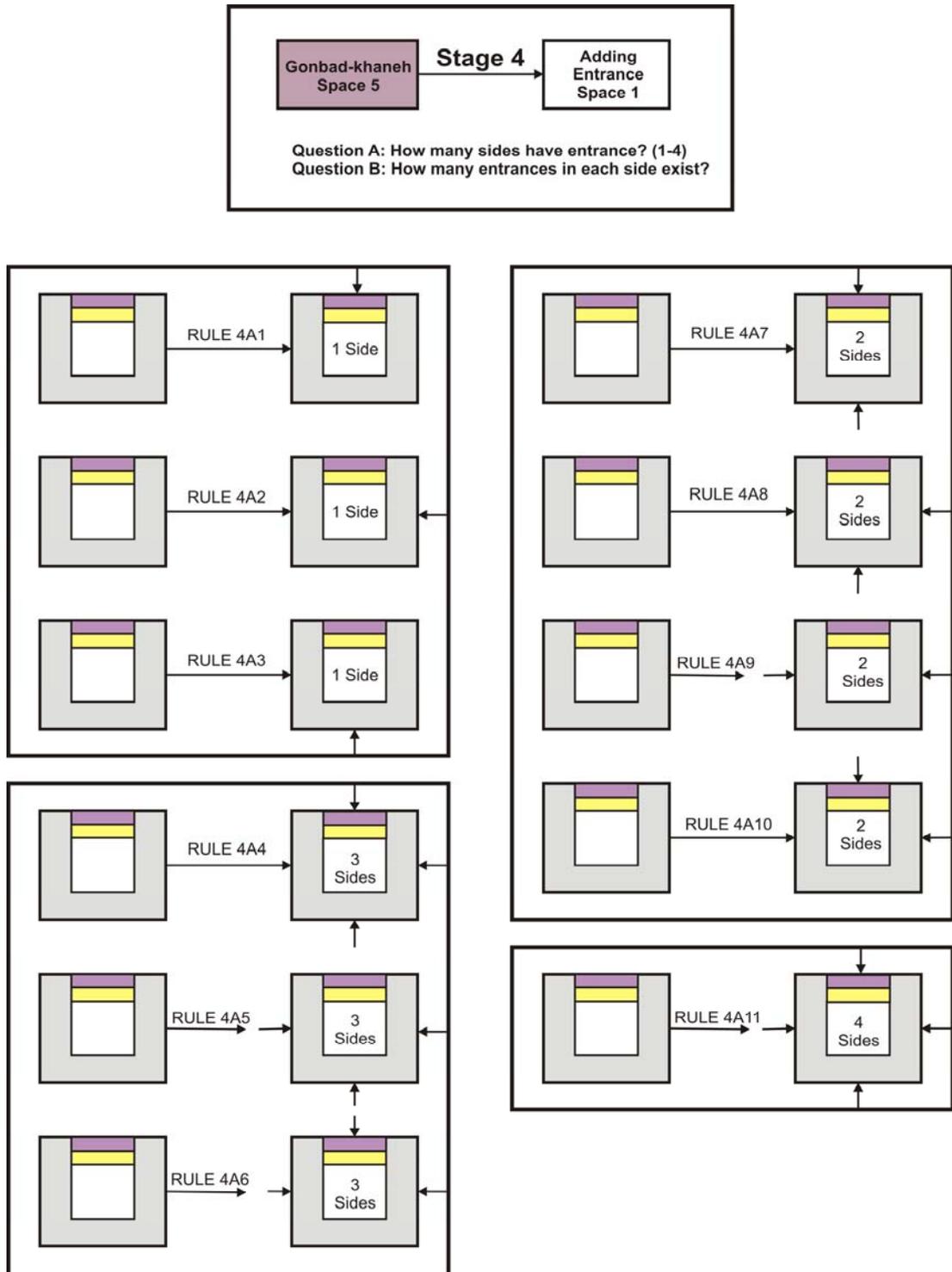
Figure 5- 40: In the first part of stage four, the location of entrances in each side of the plan is defined. The plan can have access to outside from one side or all the four sides.

In Figure 5- 40, one entrance has been added to the plan. There are nine shape rules for adding it to the plan.
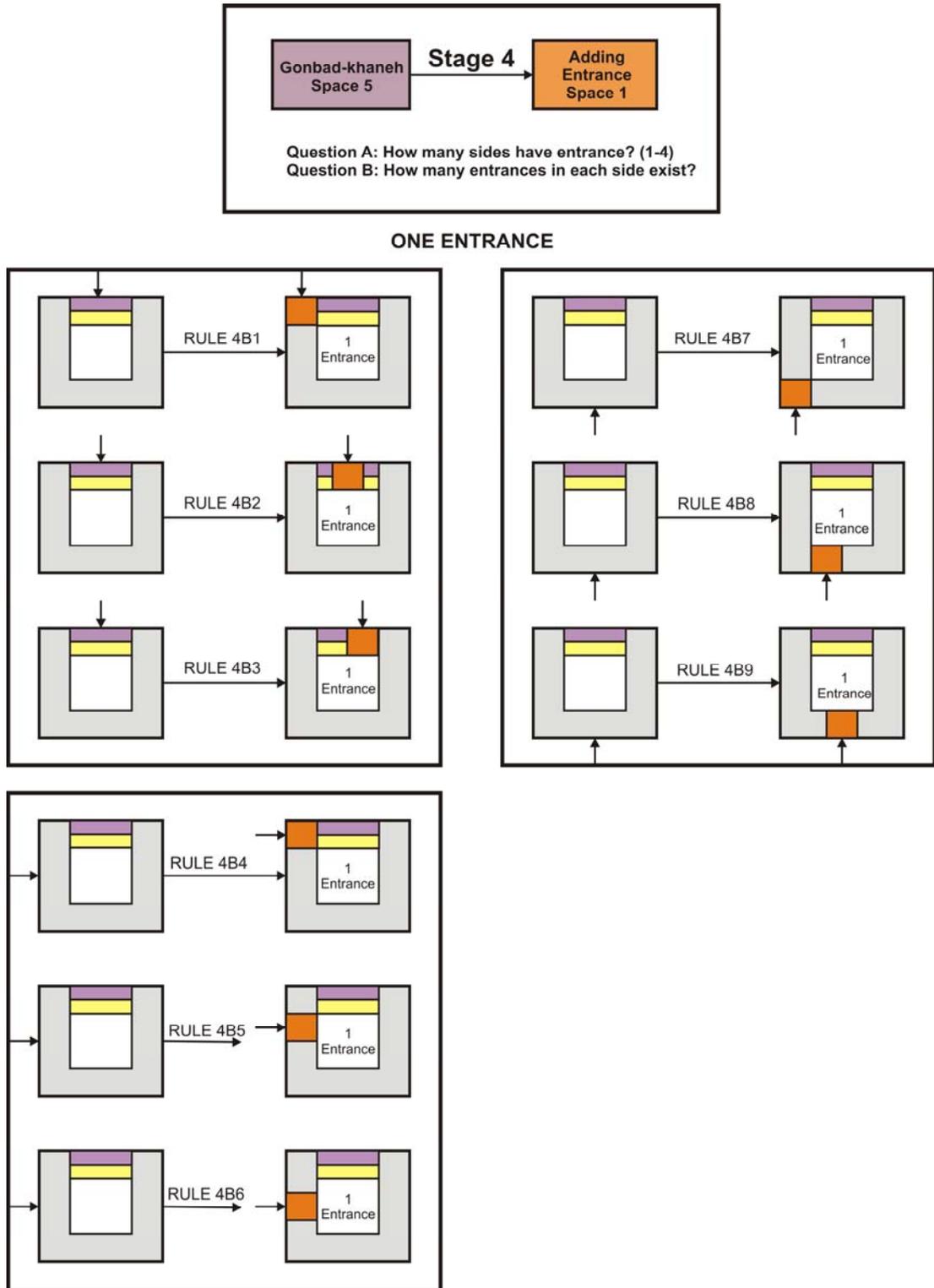
Figure 5- 41: In the second part of stage four, the number and the exact location of the entrances are defined. In this figure, nine different possibilities of locating one entrance in the layout have been shown by three different groups of the shape rules.

In Figure 5- 42, two entrances have been added in each side. There are ten possibilities for having two entrances in each side. These shape rules have been shown in three groups.
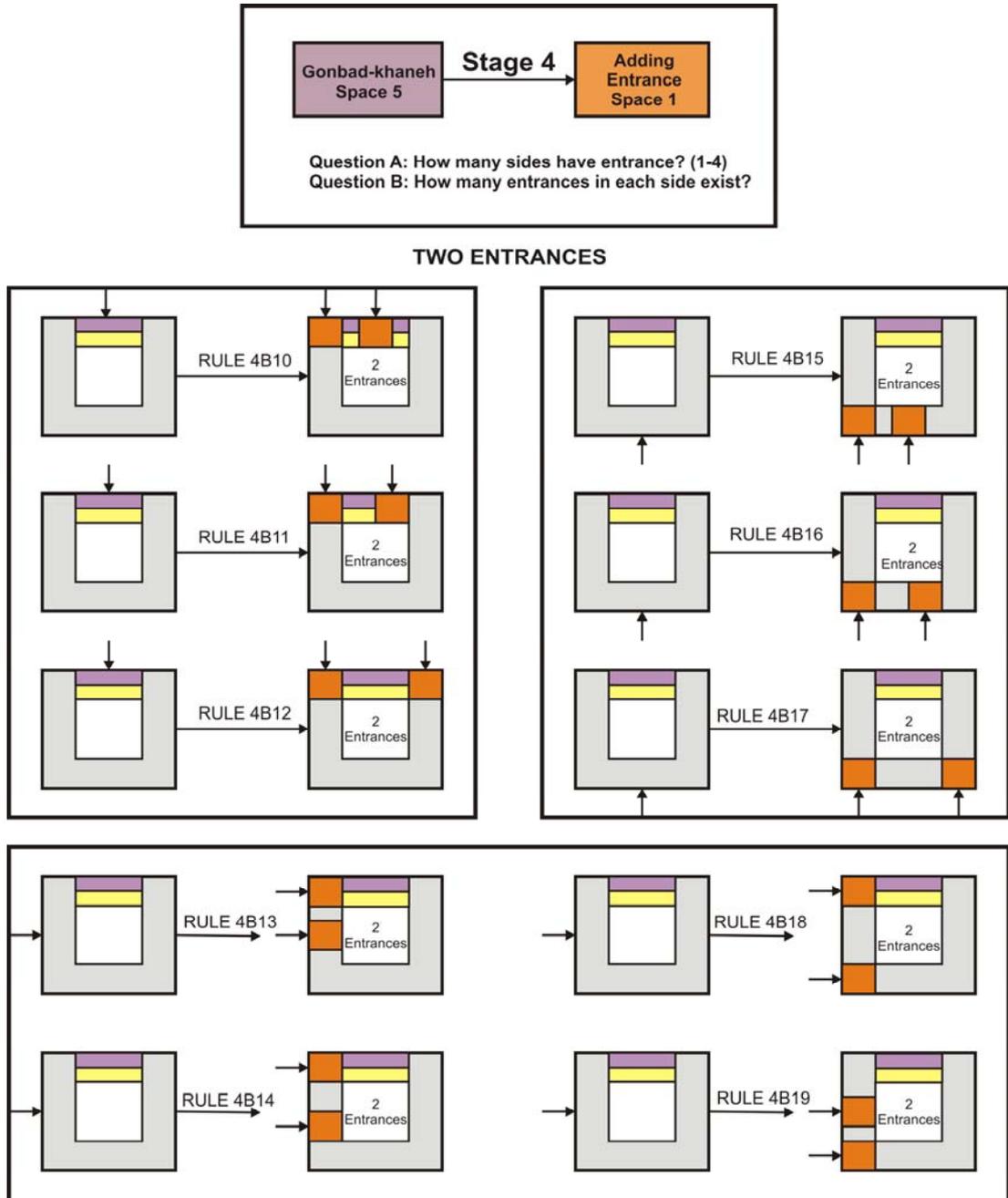
Figure 5- 42: In the second part of stage four, the number and the location of entrances have been specified by shape rules. In this figure, ten different possibilities of locating two entrances in three different groups have been shown.

In Figure 5- 43, three or more entrances in each side have been considered. However, so many entrances are rare in the one-courtyard mosques.
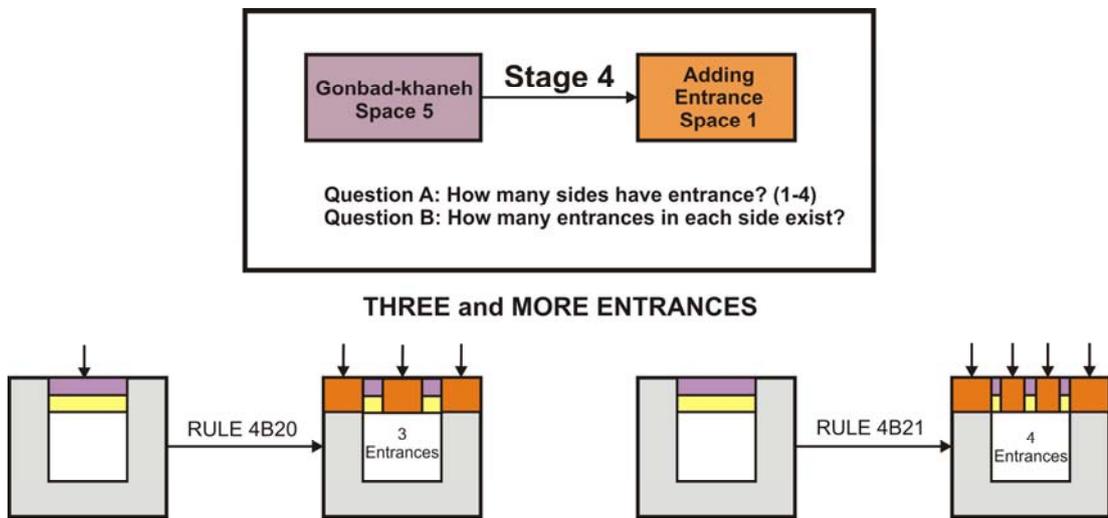
Figure 5- 43: In this figure, the possibilities of adding more than three entrances in the mosque layout have been shown by shape grammar rules.

5.3.2.5 Stage 5

In stage five, vestibule is added to the plan layout. Because of the high connectivity of vestibule and entrance, they are located next to each other. However, there are some cases that the entrance is directly opens to other spaces. This possibility has been considered by rule 51 (Figure 5- 44).
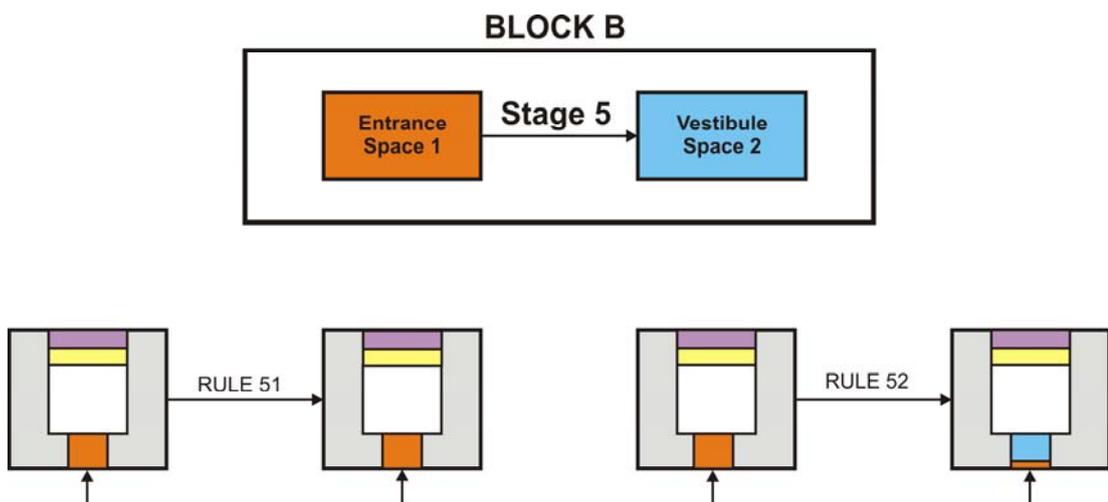
Figure 5- 44: In stage five, vestibule is added to the plan layouts. However, not all the entrances have vestibule, which have been considered in rule 51.

5.4   Summary

In this chapter, a group of Persian mosque plans were studied by shape grammar and at the end, the Persian mosque shape grammar was presented.

The shape grammar analysis in this chapter included studying the plans and their characteristics, finding the spatial relations between the spaces of the Persian mosques, introducing the sequence of applying the shape grammar rules and defining the shape grammar rules.

In order to find essential reappearing elements of the plans, the mosque plans were studied. Spatial relations constrained the ways that spaces could be combined with one another. In order to uncover them, the mosque circulation patterns and the characteristics of the spaces were studied. They revealed four simple important recurring characteristics in Persian mosque plans: (1) qebleh: it is a wall in the prayer hall which faces Mecca and all prayers are directed towards it; (2) segregation of men and women in the mosque; (3) the use of courtyard: Persian mosques have at least one courtyard which is an open space surrounded by walls with a pool in the middle of it; and (4) high connectivity between some spaces: there are high connectivity between some single, independent spaces in the plans which are always found together in the plans; they are (a) the eivan and the gonbad-khaneh; and (b) the entrance and the vestibule (Figure 5- 34). These spatial relations are simple compositional ideas and are the key to shape grammars. They provided contexts for adding the shapes to create designs in the next part.

Based on these spatial relations, a certain sequence of applying the shape grammar rule was defined (Figure 5- 35). This sequence allowed the shape grammar rules to proceed in a way to create a complete mosque plan. The phenomena of high connectivity between spaces were also considered in this sequence, by introducing two blocks in the sequence: block (A) the eivan – space 6 and the gonbad-khaneh – space 5; and block (B) the entrance – space 1 and the vestibule – space 2.

Then, the shape grammar rules of the simple plans were introduced. They consist of five stages. They apply to the initial shape, which is the prayer hall or the shabestan. These stages which include two group blocks are as following: (1) defining the courtyard or space 3; (2) defining the eivan or space 6 (part one of block A); (3) defining the gonbad-khaneh or space 5 (part two of block A); (4) defining the entrance or space 1 (part one of block B); (5) the vestibule or space 2 definition (part two of block B).The results of applying these rules are simple one-courtyard plans.

5.5   Conclusion

The classification of Persian mosques by shape grammar works as a boundary object to referee and to support negotiations around which similarities and differences can be articulated. This interpretation of classification means that classes can be customised to the user requirements, but also have common identities. Here, some of the common characteristics of Persian mosque will be discussed.

5.5.1   Courtyard and Shabestan

As it was mentioned before, courtyard is an important element in the Persian mosque plans. All of the case studies have at least one courtyard. A mosque's courtyard is often an open space leading to the main spaces of the mosque. Mostly, it is strategically located in the middle of the circulation, just after the entrance/the vestibule, and before the prayer hall.

Another important element of Persian mosque plan is the shabestan or the prayer hall. The shabestan is a specific form of prayer hall, a hypostyle prayer hall in a mosque. As the main function of mosque, praying, happens in the shabestan or the prayer hall, they are indeed the most important spaces in the mosque.

Therefore, the relation of the courtyard and the shabestan (or the prayer hall in the general term) is the most important factor in the design of Persian mosques. This important feature formed the first stage of the present shape grammar. Based on the results of that stage, the layout of eight plan types was produced (Figure 5- 45); for

example the plan of the Sarab congregational mosque (Figure 5- 46) is exactly like the result of applying rule 18.
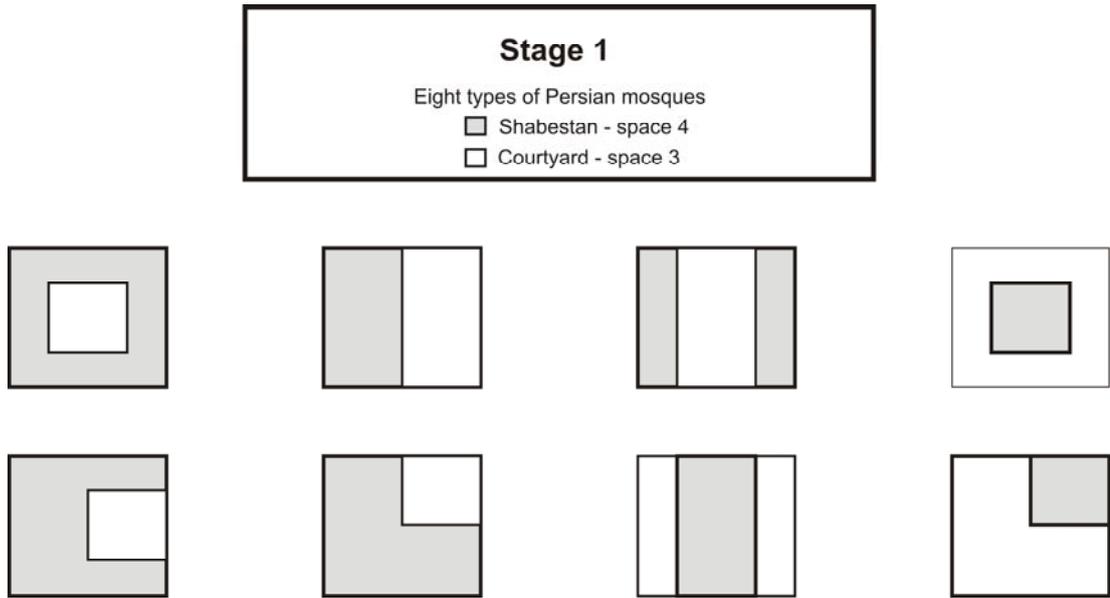
Figure 5- 45: Eight main types of Persian mosque plans based on the results of stage one
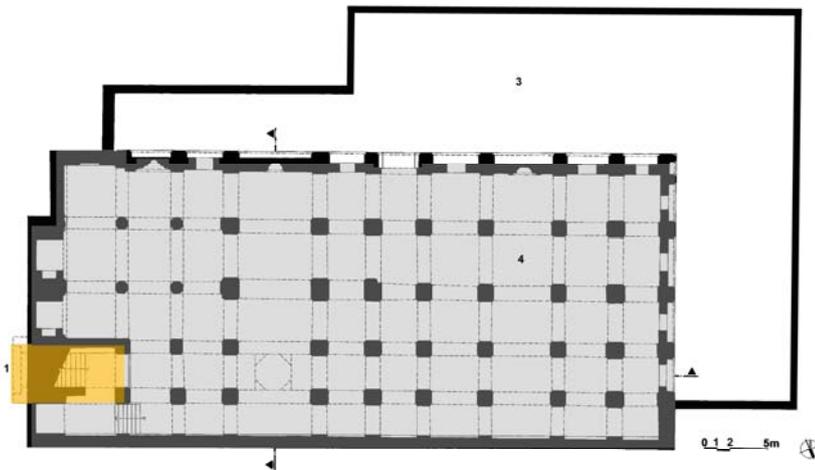
Figure 5- 46: The plan of Sarab congregational mosque is exactly like the result of stage one after applying rule 18.

5.5.2   High connectivity

The circulation patterns of the plans revealed connectivity between spaces in the plans. These spaces are always found together in the plans. It was discussed that

there are two groups of such spaces; (1) the eivan and the gonbad-khaneh; and (2) the entrance and the vestibule. If both of these spaces appear in a plan, they will be together. This characteristic was considered in the shape grammar rules with defining the two blocks in the shape grammar. Another example of such connectivity in the plan of Sabzevar congregational mosque (Figure 5- 47) has been presented here.
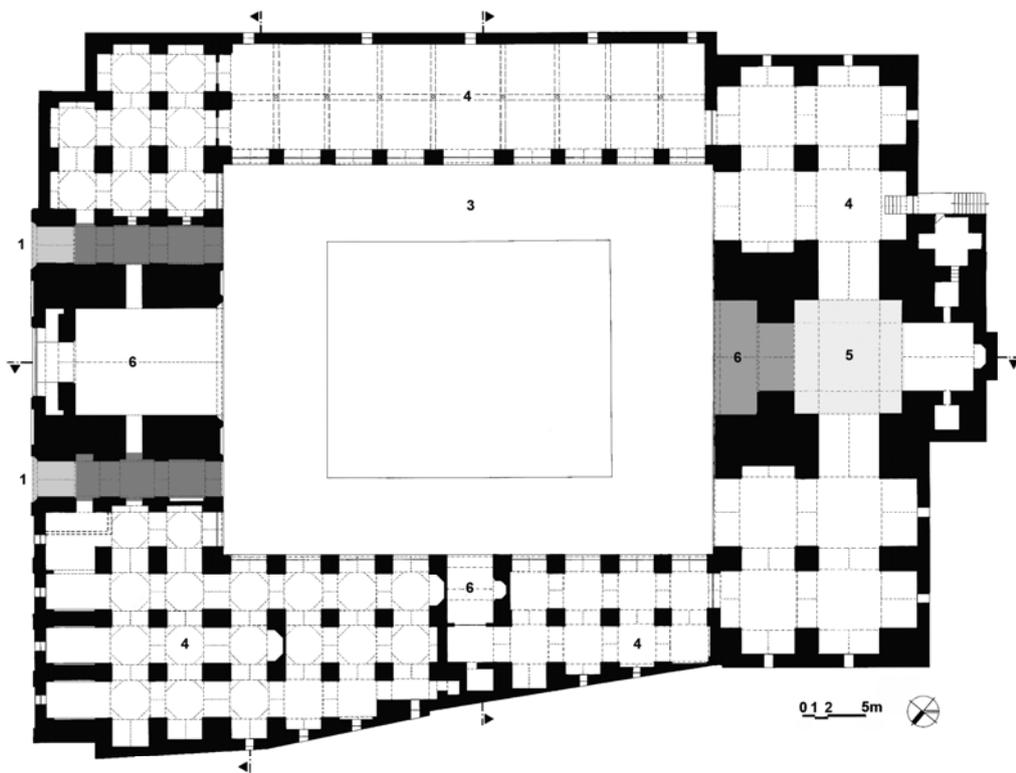
Figure 5- 47: Another example of connectivity between space 1 (the entrance) and space 2 (the vestibule); and space 5 (the gonbad-khaneh) and space 6 (the eivan) in the plan of the Sabzevar congregational mosque

5.5.3   Conclusion

This chapter illustrated a move from words and descriptions towards categorisation and classification of the Persian mosques by shape grammar. The existing sources

about these mosques are descriptive, casual and intuitive. As was mentioned before, the only existing classification of Persian mosques is based on the size and the importance of mosques: (1) the local mosque which is smaller; and (2) the main mosque or congregational mosque where the Friday prayer is recited. These classes are highly individual and unreliable.

Therefore, Persian mosque plans were studied by shape grammar. The result is a language of Persian mosque designs which is systematic, descriptive and analytic. The present prototypes represent the mental process of the categorisation and reveal both the similarities and the differences in the Persian mosque plans. However, it needs to be recognised here that there are always multiple ways for communicating knowledge, thus there can always be ambiguity in any categorisation.

This background will be considered as a foundation for the discussion of the next chapter. In the next chapter, the present Persian mosque shape grammar will be verified.

Chapter 6: Implementation of Persian mosque grammar

6.1   Introduction

In the previous chapter, Persian mosque grammar was presented. This grammar is based on a corpus of eighteen Persian mosques. Based on their characteristics and the spatial relations in their plans, a sequence and shape rules were defined. These rules are defined for characterising formal compositional aspects of mosque plans. This chapter begins with this grammar in order to verify them. Moreover, it is used for analysing and describing plans individually by distinguishing certain characteristics common to them. The result is a classification of the given plans which is presented at the end.

6.2   Implementation of the Persian mosque shape grammar

The plans of samples of mosques have been previously characterised by using a system of Persian mosque shape grammar. In this chapter, this system is subject to a verification process. Moreover, it provides a constructive description for each one of these plans. It includes a set of operations by which the plan can be generated from the initial shape. A brief explanation will accompany them.

6.2.1   Abhar Congregational Mosque

Abhar congregational mosque has two courtyards. However, because of its simple plan, there was no need to use the complex shape grammar rules in this case. Its plan has been produced by 7 rules shown in Figure 6- 1 and Figure 6- 2.

Abhar Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 14		First stage: In this stage prayer hall and courtyard are defined.
rule 2A2		Second Stage: In this stage, 1 side has an eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 33		Third Stage: Eivan is replaced by gonbad-khaneh.
rule 4A2		Fourth Stage: One side has access to outside.
rule 4B18		Fourth Stage: The plan has two entrances in one side of the plan.
rule 51		Fifth Stage: The entrances have no vestibule.
		This plan has a unique shape that has been caused by several alterations through its history and site constraints.
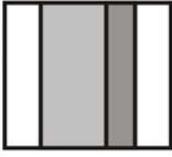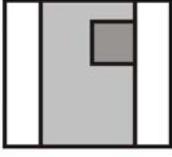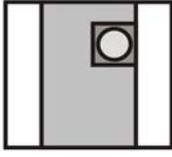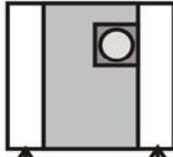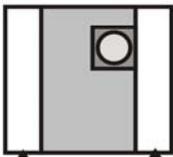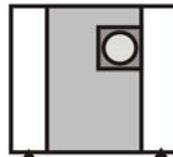
Figure 6- 1: Shape grammar rules for Abhar congregational mosque in details

The unique shape of the plan is due to the constraints of the site. Another important characteristic of the plan is the existence of gonbad-khaneh (or dome) without an eivan. This plan is one of the few plans which with this feature. This situation was considered in rule 33 which replaces a gonbad-khaneh with an eivan. But, this situation is very rare.
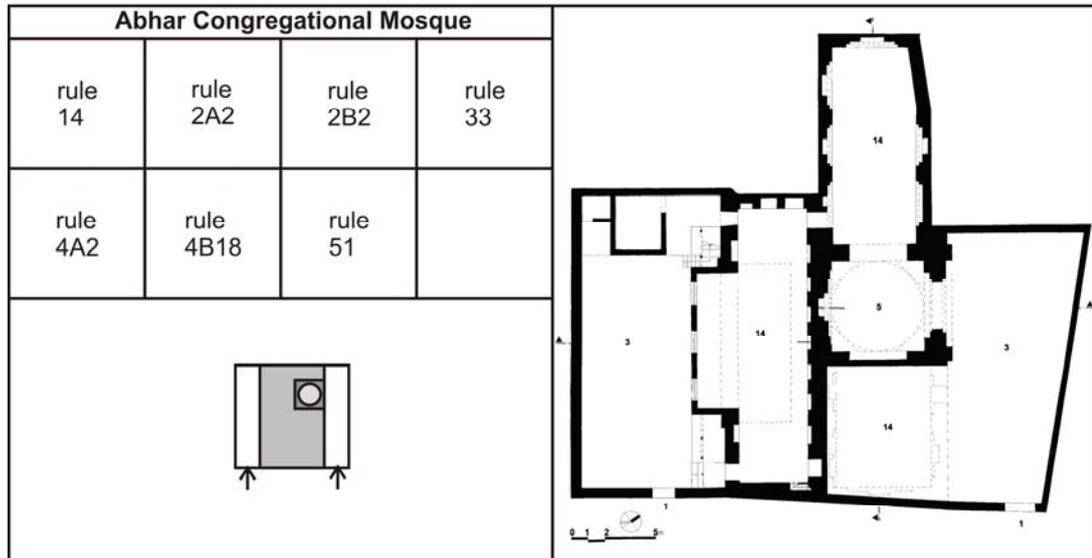
Figure 6- 2: shape grammar rules for Abhar congregational mosque

6.2.2 *Ardestan Congregational Mosque*

The Ardestan mosque has a complex plan and unique shape of the entrances due to the site constrains. The grey area was not included in the analysis.
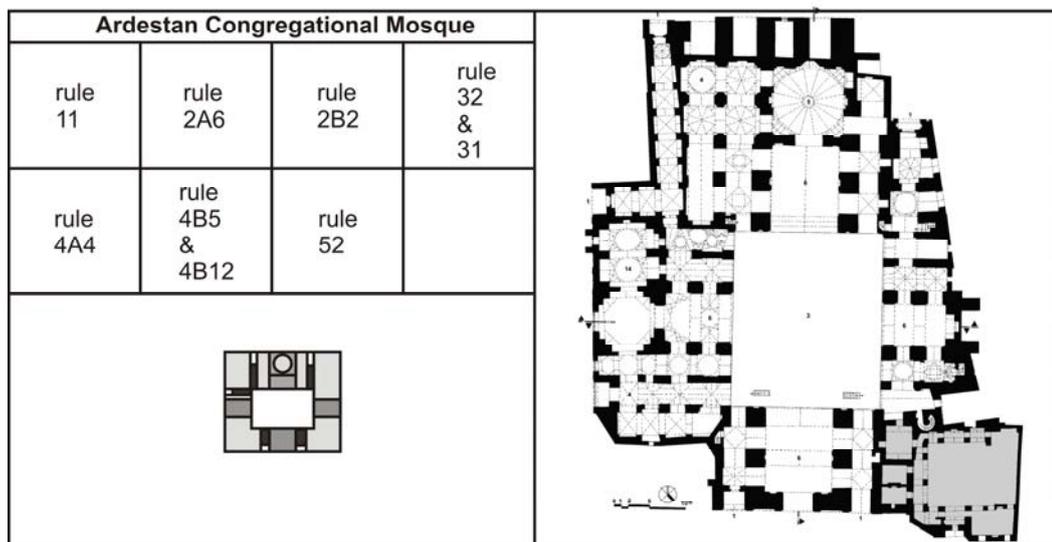

Figure 6- 3: shape grammar rules for Ardestan congregational mosque

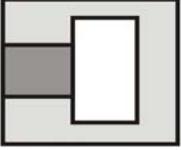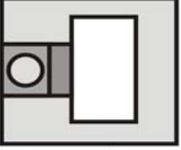| Ardestan Congregational Mosque		
Rule	Derivation	Explanation
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A6		Second Stage: In this stage, 4 sides have eivans.
rule 2B2		Second Stage: One eivan is added to each sides.
rule 32 & 31		Third Stage: Only one of the eivans has gonbad-khaneh.
rule 4A4		Fourth Stage: Three sides have access to outside.
rule 4B5 & 4B12		Fourth Stage: The entrances have been added to the plan.
rule 52		Fifth Stage: The entrances have vestibules.
		The grey area in the plan is not included in the shape grammar analysis.
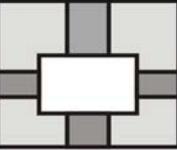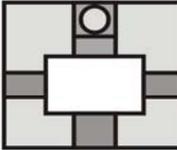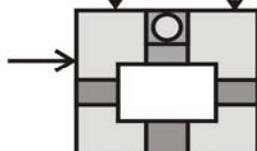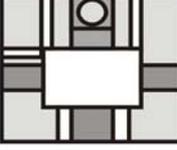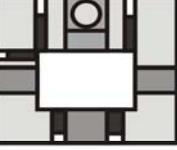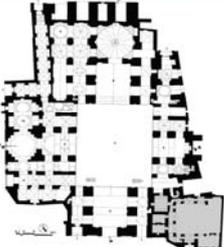
Figure 6- 4: Shape grammar rule for Ardestan congregational mosque in details

Babol Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A2		Second Stage: In this stage, 1 side has been chosen for adding an eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 32		Third Stage: In this stage, a gonbad-khaneh is added to the plan.
rule 4A9		Fourth Stage: Two sides have access to outside.
rule 4B5		Fourth Stage: Two entrances have been added to the plan.
rule 52		Fifth Stage: The entrances have vestibules.

Figure 6- 5: Shape grammar rules for Babol congregational mosque in details

6.2.3   Babol Congregational Mosque

Some characteristics of this mosque are typical for Persian mosque plans, such as one courtyard in the middle of the mosque (rule 11), two entrances, and one big eivan in one side (rule 2B2). However, this mosque has chambers facing outside that are not part of analysis here, as these chambers are used by religious students and have educational function; these spaces are out of the scope of this study.
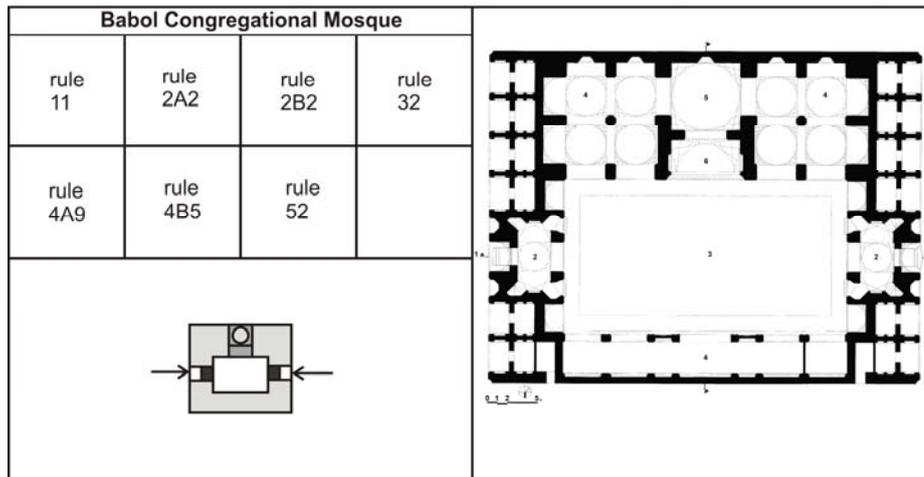
Figure 6- 6: shape grammar rules for Babol congregational mosque

6.2.4   Boroujerd Congregational Mosque

The simple shape of Boroujerd congregational mosque is typical for Persian mosque plans, such as rule 11 for locating the courtyard in the middle of the plan, rule 2B2 to locate an eivan in one side of the courtyard, and two entrances with vestibules.
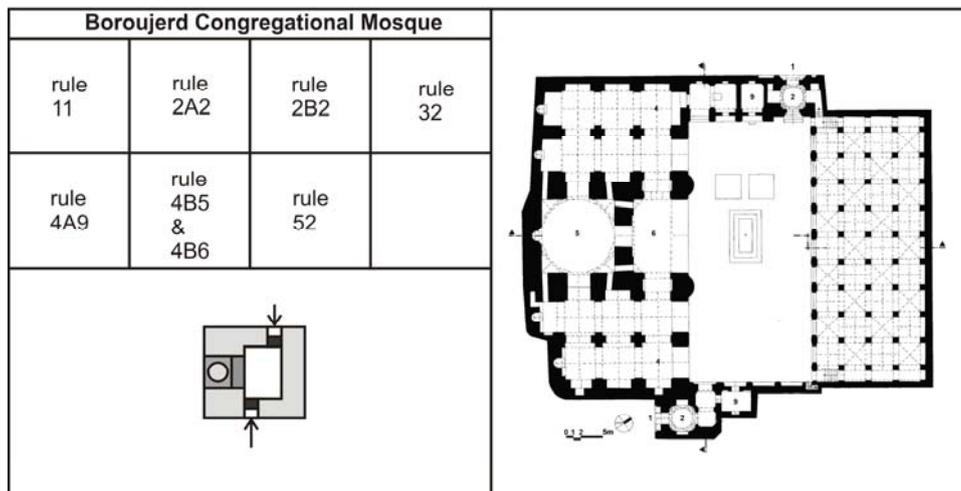
Figure 6- 7: shape grammar rules for Boroujerd congregational mosque

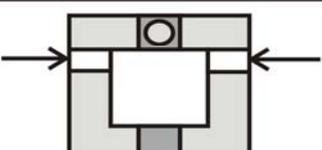| Boroujerd Congregational Mosque		
Rule	Derivation	Explanation
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A2		Second Stage: In this stage, 1 side have been chosen for adding an eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 32		Third Stage: In this stage, a gonbad-khaneh is added to the plan.
rule 4A9		Fourth Stage: Two sides have access to outside.
rule 4B5 & 4B6		Fourth Stage: Two entrances have been added to the plan.
rule 52		Fifth Stage: The entrances have vestibules.
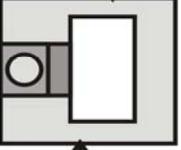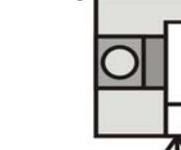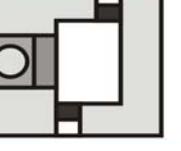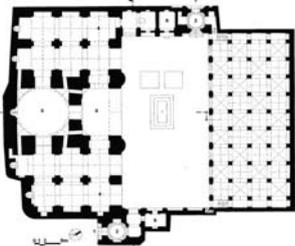
Figure 6- 8: Shape grammar rules for Boroujerd congregational mosque in details

Chaleshtor Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		**First stage:** In this stage prayer hall and courtyard are defined.
rule 2A4		**Second Stage:** In this stage, 2 sides have been chosen for adding eivans.
rule 2B2		**Second Stage:** One eivan is added to each side.
rule 32 & 33		**Third Stage:** In this stage, one of the sides has gonbad-khaneh, but the other does not.
rule 4A9		**Fourth Stage:** Two sides have access to outside.
rule 4B5		**Fourth Stage:** Two entrances have been added to the plan.
rule 51 & 52		**Fifth Stage:** One of the entrances has vestibule.
		The constraints of the site is the reason behind the unique shape of this plan.
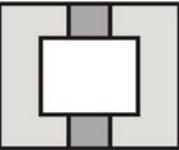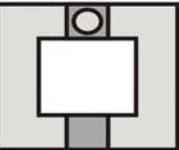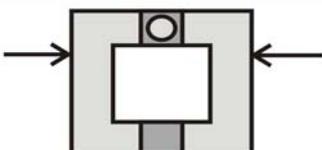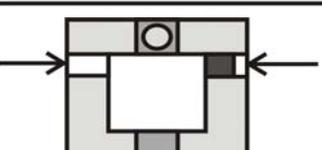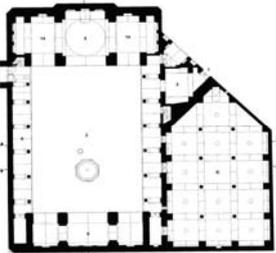
Figure 6- 9: shape grammar rules for Chaleshtor congregational mosque in details

6.2.5   *Chalestor Congregational Mosque*

This mosque has some typical characteristics of Persian mosque, such as one big eivan in one side of the courtyard (rule 2B2), the location of the courtyard in the middle of the plan (rule 11), and two entrances in the two sides of the mosque; however it has some unique characteristics too, such as replacing eivan with gonbad-khaneh (rule 33) which has been used very rarely.
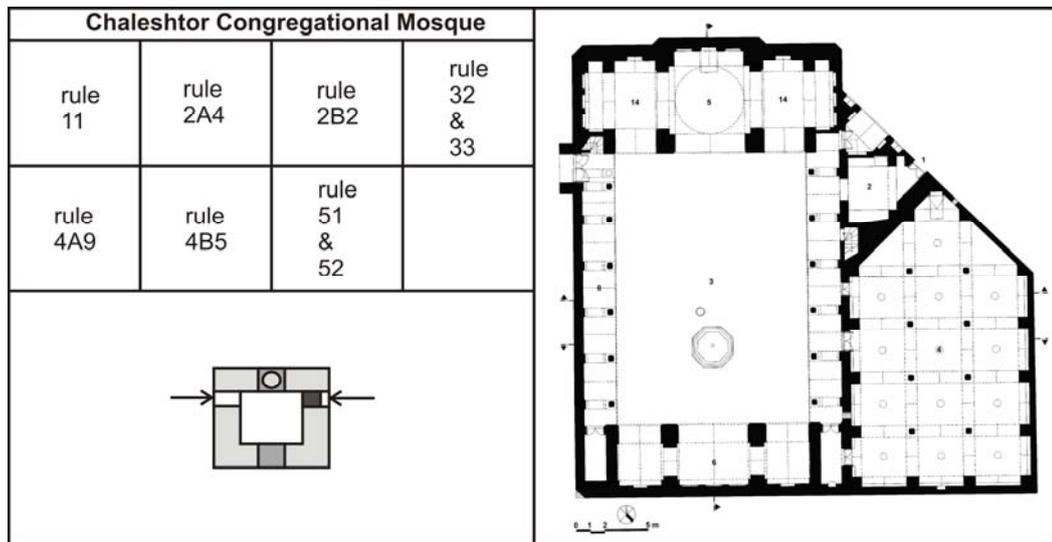

Figure 6- 10: shape grammar rules for Chaleshtor congregational mosque

6.2.6   *Damghan Congregational Mosque*

This mosque has a common characteristic with two entrances; but some unique features too, such as courtyard in the corner and three eivans in one side. The grey area in the plan is recently built and was not included in the shape grammar analysis.
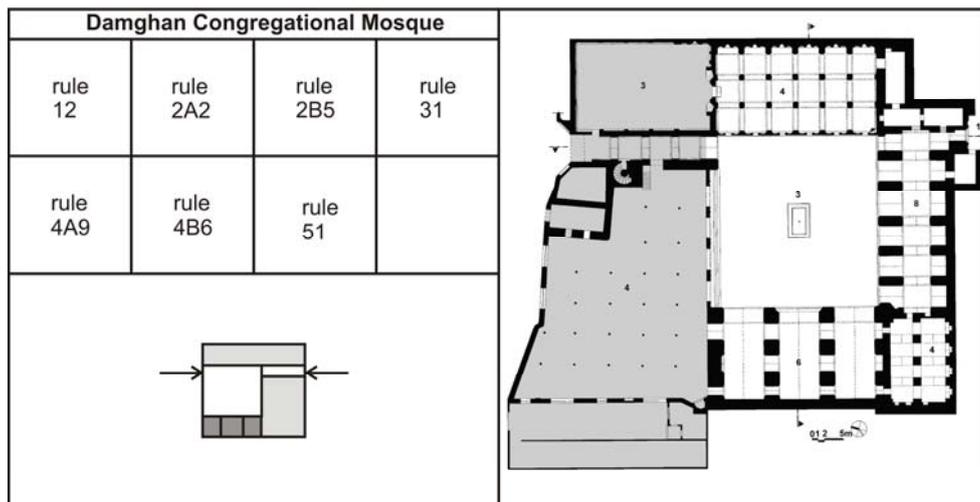

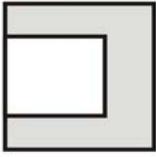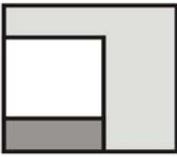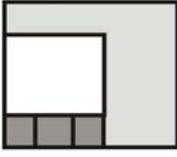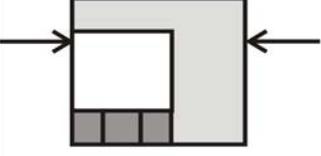**Figure 6- 11: shape grammar rules for Damghan congregational mosque**

Damghan Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 12		First stage: In this stage prayer hall and courtyard are defined.
rule 2A2		Second Stage: In this stage, 1 side has been chosen for adding eivans.
rule 2B5		Second Stage: Three eivans are added to the chosen side.
rule 31		Third Stage: The plan has no gonbad-khaneh.
rule 4A9		Fourth Stage: Two sides have entry to the mosque.
rule 4B6		Fourth Stage: The two entrances are added to the plan.
rule 51		Fifth Stage: The entrance does not have vestibule.
		The grey areas in the plan are new, and therefore are not included in the shape grammar analysis.
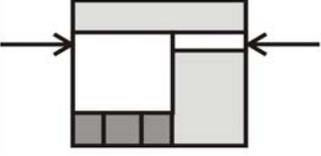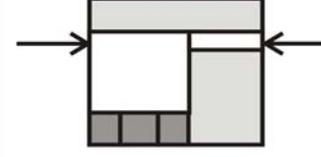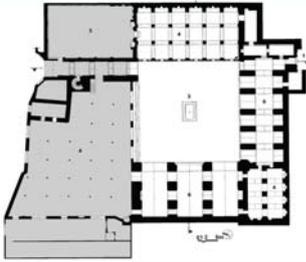
Figure 6- 12: Shape grammar rules for Damghan congregational mosque in details
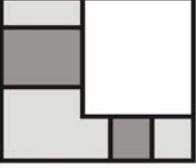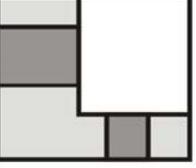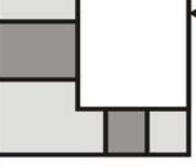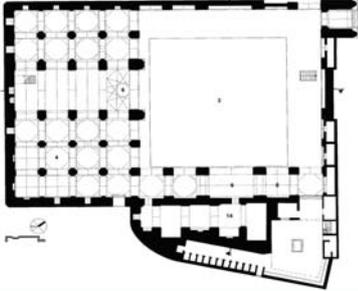
Dezful Congregational Mosque		
Rule	Derivation	Explanation
rule 16		First stage: In this stage prayer hall and courtyard are defined.
rule 2A3		Second Stage: In this stage, 2 sides have been chosen for adding eivans.
rule 2B2		Second Stage: Eivans are added to the chosen sides.
rule 31		Third Stage: The plan has no gonbad-khaneh.
rule 4A2		Fourth Stage: Only one side has entry to the mosque.
rule 51		Fifth Stage: The entrance does not have vestibule.

Figure 6- 13: Shape grammar rules for Dezful congregational mosque in details

6.2.7 Dezful Congregational Mosque

This mosque is one of the few plans which have a courtyard in the corner of the plan; only Tabriz mosque has the same characteristic. However, it has one big eivan in one side which is the most common characteristics of Persian mosques or rule 2B2.
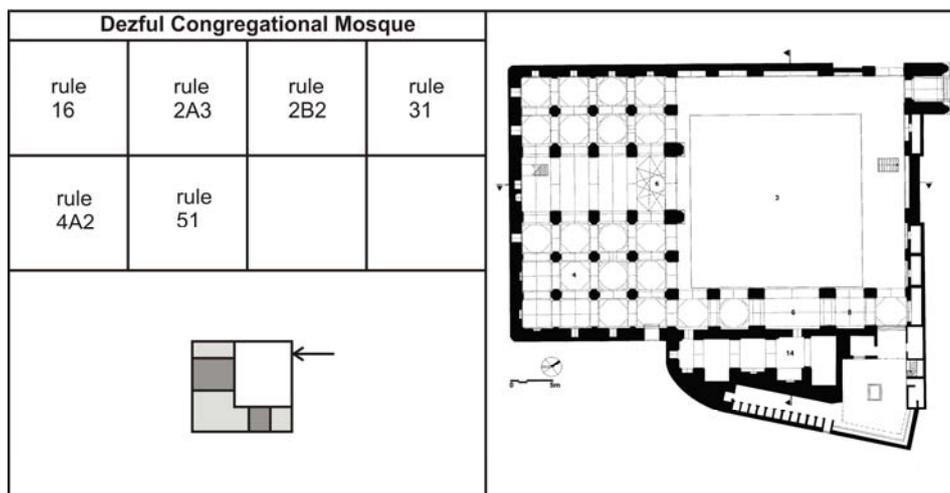

Figure 6- 14: shape grammar rules for Dezful congregational mosque

6.2.8 Orumiyeh Congregational Mosque

In this mosque, chambers (space 9) have replaced the prayer hall, but this change has not been produced here. The plan has used a common rule (rule 2B2), but at the same time has a rare characteristic by replacing eivan with gonbad-khaneh (rule 33). Only two other mosques have this arrangement: Abhar and Chaleshtor. This mosque has some recent extensions that were not included in the analysis.
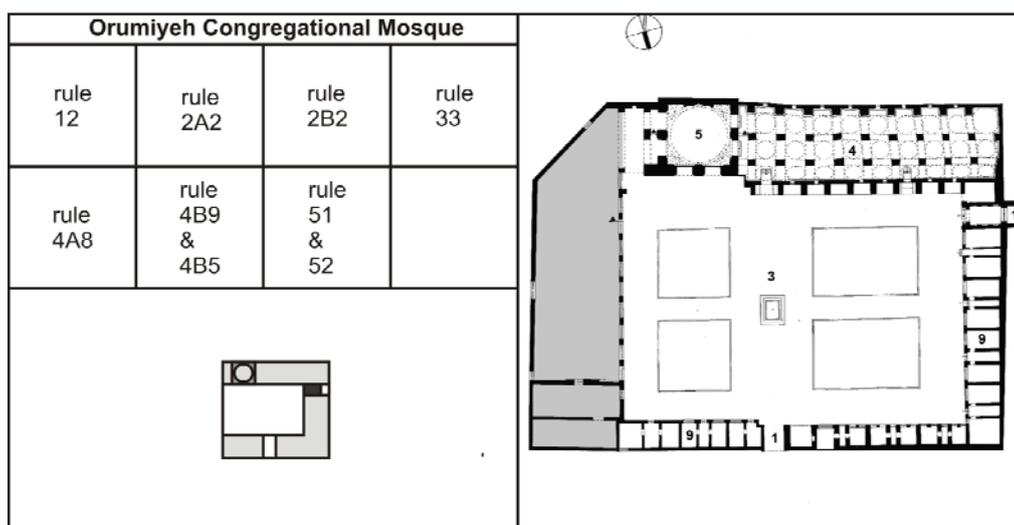

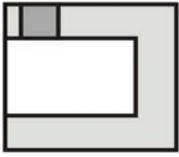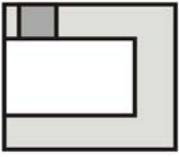**Figure 6- 15: shape grammar rules for Orumiyeh congregational mosque**

Orumiyeh Congregational Mosque		
Rule	Derivation	Explanation
rule 12		**First stage:** In this stage prayer hall and courtyard are defined.
rule 2A2		**Second Stage:** In this stage, 1 side has been chosen for the eivan.
rule 2B2		**Second Stage:** One eivan is added to the chosen side.
rule 33		**Third Stage:** In this stage, a gonbad-khaneh is added.
rule 4A8		**Fourth Stage:** Two sides have been chosen for the entries.
rule 4B9 & 4B5		**Fourth Stage:** Two entrances have been added to the plan.
rule 51 & 52		**Fifth Stage:** One entrance has a vestibule.
		In this plan, the grey areas have been added recently. Thus, they are included in the shape grammar analysis.

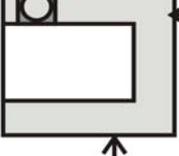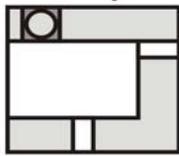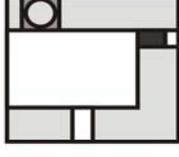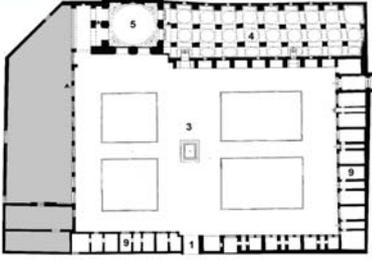**Figure 6- 16: Shape grammar rules for Orumiyeh congregational mosque in details**

Oshtorjan Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		**First stage:** In this stage prayer hall and courtyard are defined.
rule 2A2		**Second Stage:** In this stage, 1 side has been chosen for the eivan.
rule 2B2		**Second Stage:** One eivan is added to the chosen side.
rule 32		**Third Stage:** In this stage, a gonbad-khaneh is added next to eivan.
rule 4A8		**Fourth Stage:** Two sides have been chosen for the entries.
rule 4B8 & 4B5		**Fourth Stage:** Two entrances have been added to the plan.
rule 51		**Fifth Stage:** The entrances have no vestibule.
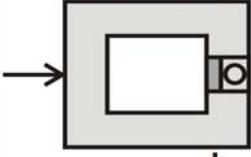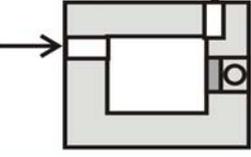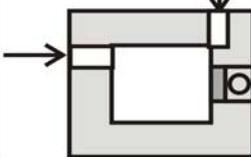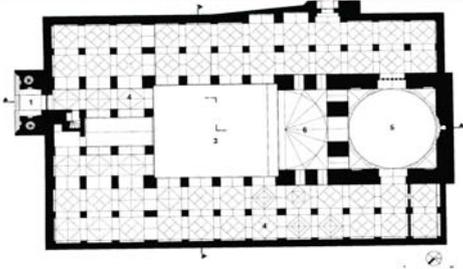
Figure 6- 17: Shape grammar rules for Oshtorjan congregational mosque in details

6.2.9 Oshtorjan Congregational Mosque

This mosque has some common features of Persian mosques, such as a courtyard in the middle of the plan or rule 11, a big eivan in one side of the courtyard or rule 2B2 and two entrances.
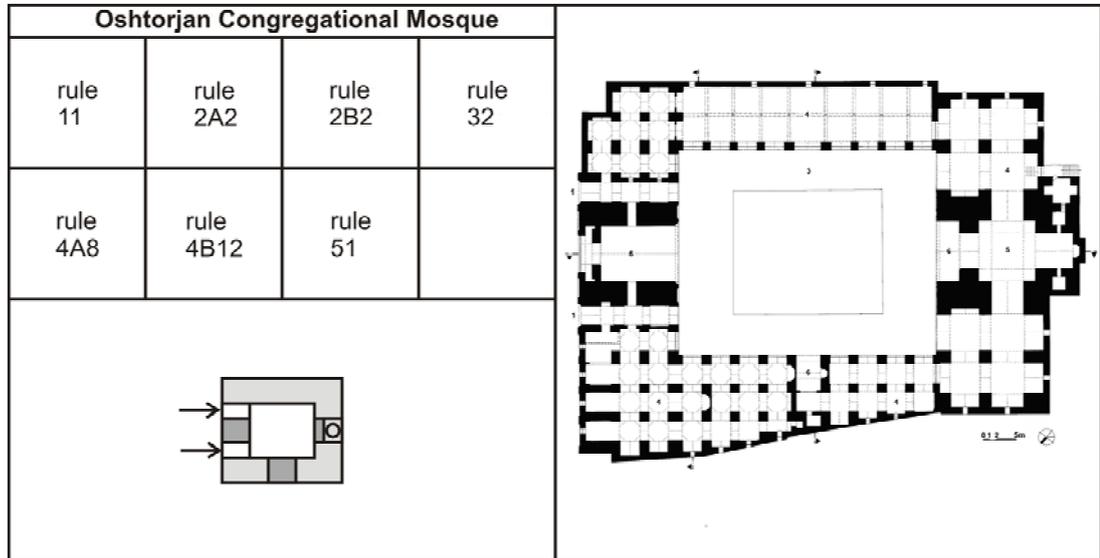
Figure 6- 18: shape grammar rules for Oshtorjan congregational mosque

6.2.10 Sabzevar Congregational Mosque

This plan has a great similarity to the plan of Oshtorjan mosque and it can be seen in the shape rules too. They have four similar rules. The shape grammar rules and the details of them are shown in Figure 6- 19 and Figure 6- 20.

Figure 6- 19: shape grammar rules for Sabzevar congregational mosque

Sabzevar Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A5		Second Stage: In this stage, 3 sides have been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to each side.
rule 32 & 31		Third Stage: In this stage, one of the eivans has gonbad-khaneh, but the others do not.
rule 4A3		Fourth Stage: One side has been chosen for the entry.
rule 4B12		Fourth Stage: Two entrances have been added to the plan.
rule 51		Fifth Stage: The entrances have no vestibule.
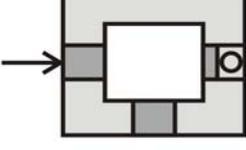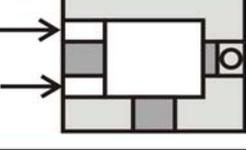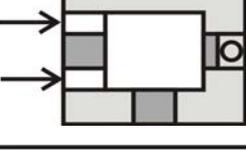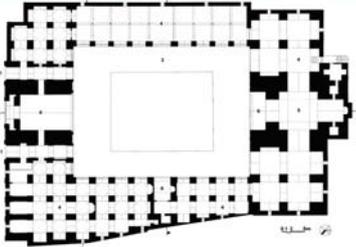
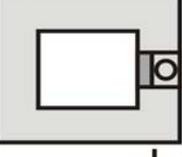**Figure 6- 20: Shape grammar rules for Sabzevar congregational mosque in details**

Sanandaj Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A6		Second Stage: In this stage, 4 sides have been chosen for the eivan.
rule 2B2 &2B4 &2B5 &2B6		Second Stage: Eivans are added to the plan.
rule 31		Third Stage: The plan has no gonbad-khaneh.
rule 4A1		Fourth Stage: One side has been chosen for entrance.
rule 4B2		Fourth Stage: One entrance has been added to the plan.
rule 52		Fifth Stage: The entrance has a vestibule.
		The original plan has a prayer hall next to the big eivan and the spaces around the courtyard are serving as chambers and lecture hall.
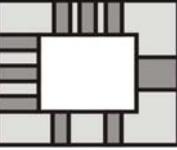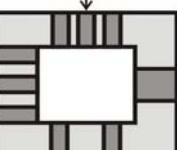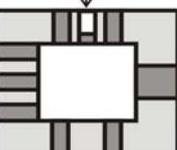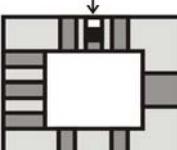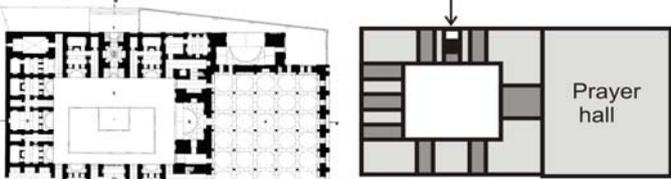
Figure 6- 21: Shape grammar rules for Sanandaj congregational mosque in details

6.2.11 Sanandaj Congregational Mosque

This mosque has a complex plan shape which is reflected in its shape grammar rules, as it has ten shape rules. This mosque has three eivans in two sides of the courtyard which is not common in a small one-courtyard mosque. However, most of the spaces around the courtyard are used for other purposes rather than prayer. Thus, another space has been added to the plan to serve as a prayer hall.
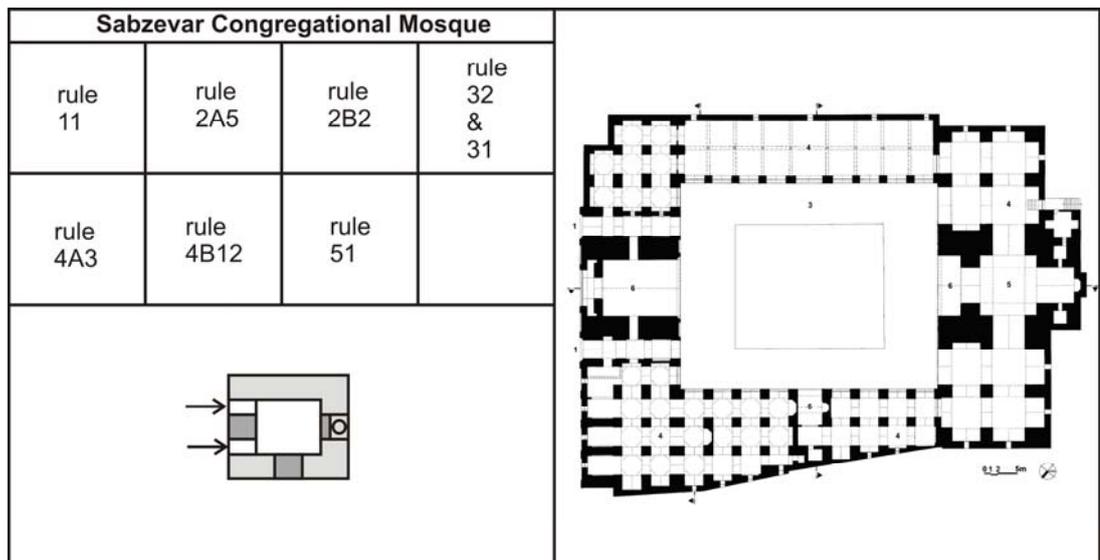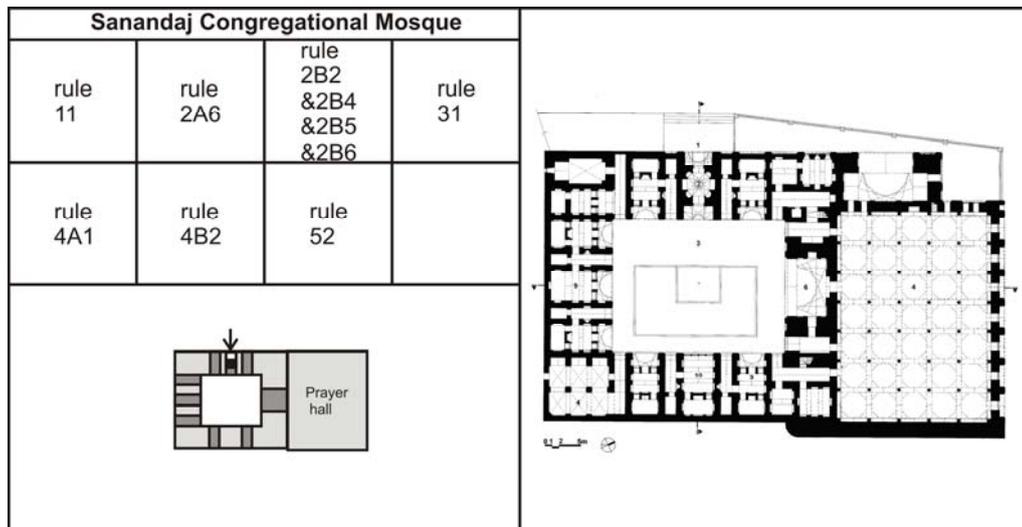

Figure 6- 22: shape grammar rules for Sanandaj congregational mosque

6.2.12 Sarab Congregational Mosque

This plan has a simple shape and by applying the rule 18 almost the whole plan structure is produced. The other rules have been applied to exclude addition of other spaces to the plan.

Figure 6- 23: shape grammar rules for Sarab congregational mosque

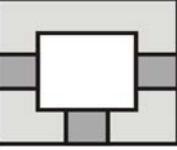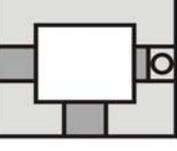|	Sarab Congregational Mosque	
Rule	**Derivation**	**Explanation**
rule 18		**First stage:** In this stage prayer hall (space 4) and courtyard (space 3) are defined.
rule 2A1		**Second Stage:** In this stage, 0 side has been chosen for the eivan. Thus, no eivan will be added.
rule 31		**Third Stage:** In this stage, no gonbad-khaneh is added.
rule 4A1		**Fourth Stage:** Only one side has been chosen for adding the entrance.
rule 4B2		**Fourth Stage:** The entrance has been added to the plan.
rule 52		**Fifth Stage:** Vestibule has been added to the plan in this stage.
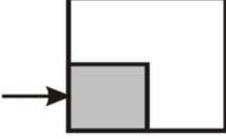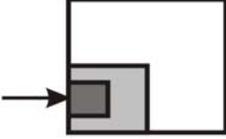
Figure 6- 24: Shape grammar rules for Sarab congregational mosque in details

Sari Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall (space 4 and 14) and courtyard (space 3) are defined.
rule 2A2		Second Stage: In this stage, 1 side has been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 31		Third Stage: In this stage, no gonbad-khaneh is added.
rule 4A8		Fourth Stage: Two sides have been chosen for the entries.
rule 4B6 & 4B9		Fourth Stage: The two entrances have been added to the plan.
rule 51 & 52		Fifth Stage: One of the entrances has vestibule and the other one does not.
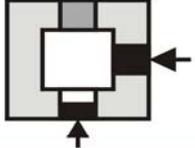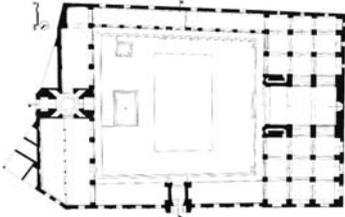
Figure 6- 25: Shape grammar rules for Sari congregational mosque in details

6.2.13 Sari Congregational Mosque

Sari congregational mosque has been altered so many times, but has some common features, such as 11, 2B2, and 51. Another common characteristic of this mosque is the existence of two entrances.
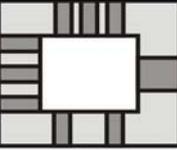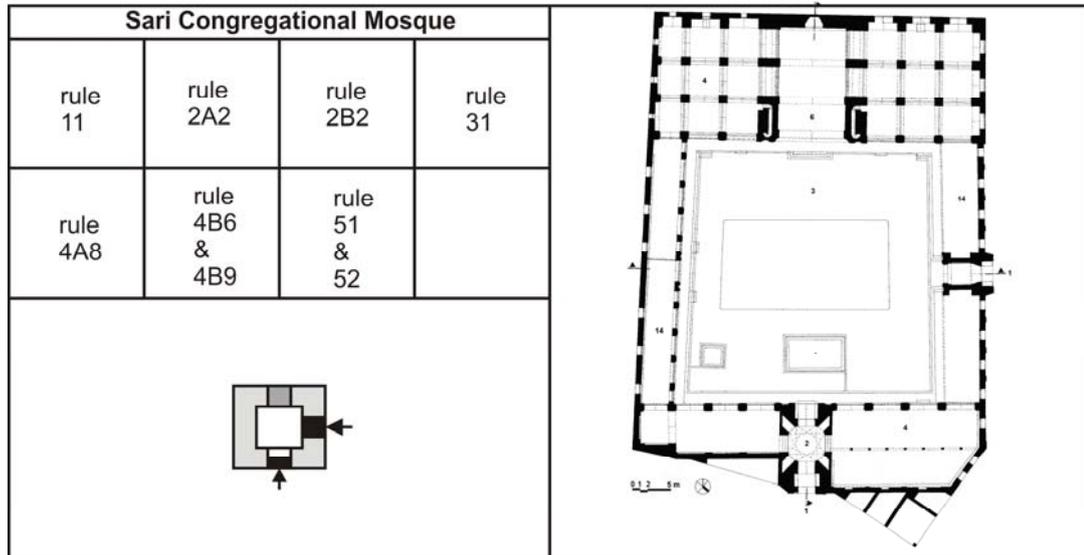

Figure 6- 26: shape grammar rules for Sari congregational mosque

6.2.14 Saveh Congregational Mosque

The shape of the plan has the typical characteristics of Persian mosques, as the shape rules shown here confirm that.

Figure 6- 27: shape grammar rules for Saveh congregational mosque

Saveh Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall (space 4 and 14) and courtyard (space 3) are defined.
rule 2A3		Second Stage: In this stage, 2 sides have been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to each chosen side.
rule 31 & 32		Third Stage: In this stage, one eivan has a gonbad-khaneh, but the other one does not.
rule 4A8		Fourth Stage: Two sides have been chosen for the entries.
rule 4B3 & 4B9		Fourth Stage: The two entrances have been added to the plan.
rule 51 & 52		Fifth Stage: One of the entrances has vestibule and the other one does not.
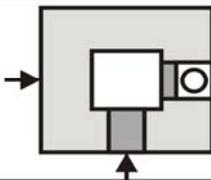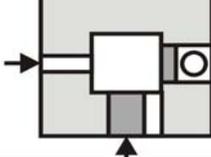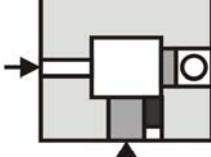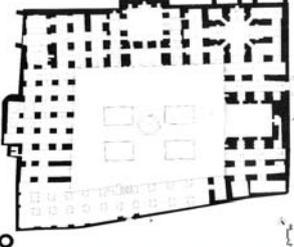
Figure 6- 28: Shape grammar rules for Saveh congregational mosque in details

Tabriz Congregational Mosque		
Rule	Derivation	Explanation
rule 16		First stage: In this stage prayer hall (space 4 and 14) and courtyard (space 3) are defined.
rule 2A2		Second Stage: In this stage, 1 side has been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 31		Third Stage: In this stage, no gonbad-khaneh is added to the plan.
rule 4A9		Fourth Stage: Two sides have been chosen for the entries.
rule 4B6		Fourth Stage: The two entrances have been added to the plan.
rule 51		Fifth Stage: The entrances have no vestibule.

Figure 6- 29: Shape grammar rules for Tabriz congregational mosque in details

6.2.15 Tabriz Congregational Mosque

The plan of this mosque has a unique shape, because of two religious schools next to it. The shape rules for this mosque are shown in Figure 6- 29 and Figure 6- 30.
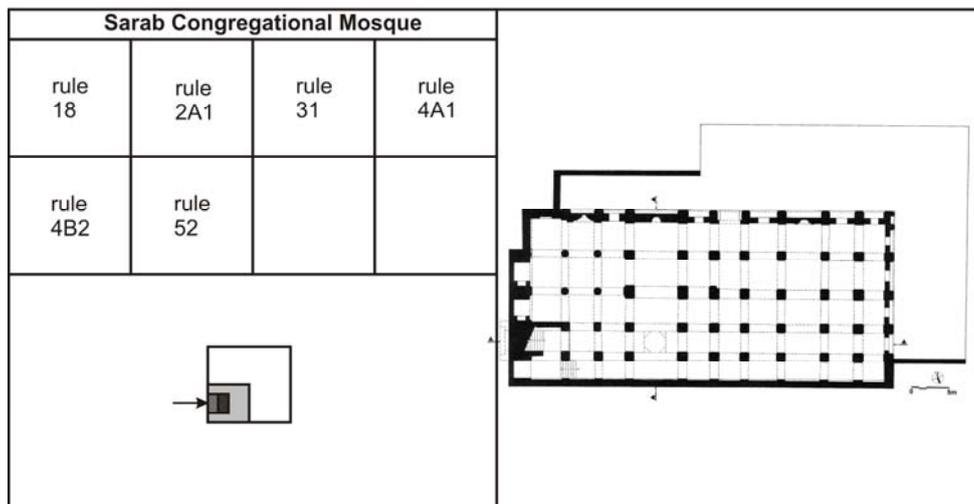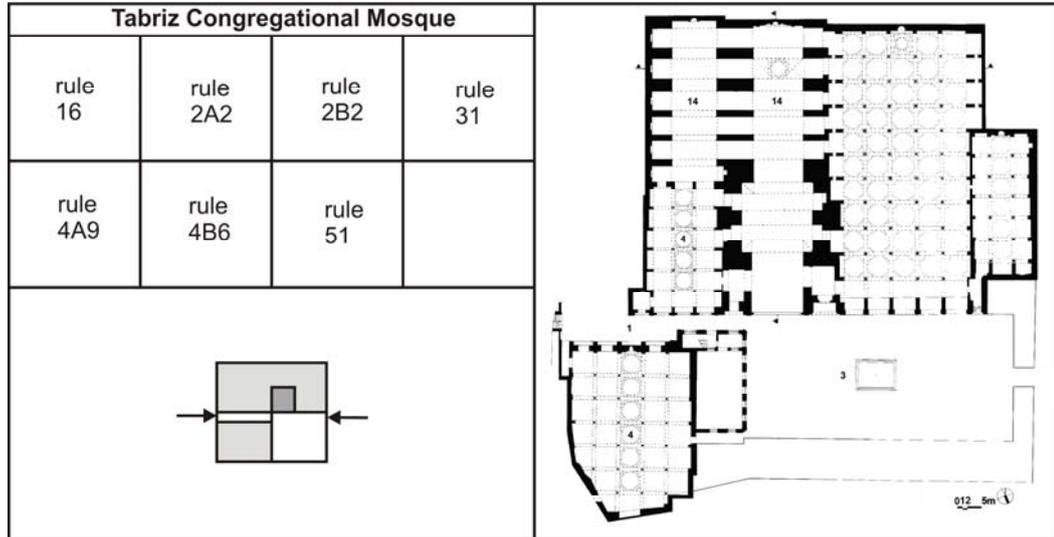

Figure 6- 30: shape grammar rules for Tabriz congregational mosque

6.2.16 Tuyserkan Congregational Mosque

The grey are in the plan of this mosque have been added recently and are used for functions not related to the mosque, thus they were not analysed here.
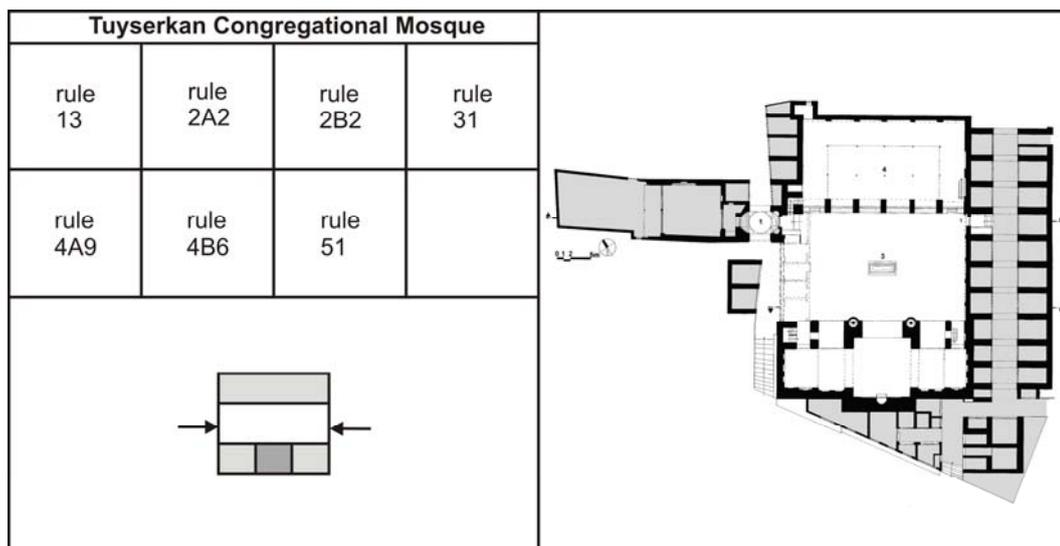
Figure 6- 31: shape grammar rules for Tuyserkan congregational mosque
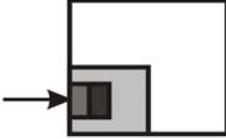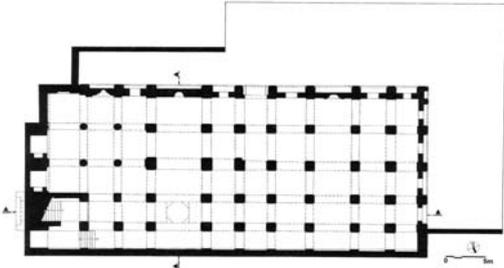
Tuyserkan Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 13		First stage: In this stage prayer hall (space 4) and courtyard (space 3) are defined.
rule 2A2		Second Stage: In this stage, 1 side has been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to the plan.
rule 31		Third Stage: In this stage, no gonbad-khaneh is added to the plan.
rule 4A9		Fourth Stage: Two sides have been chosen for the entries.
rule 4B6		Fourth Stage: The two entrances have been added to the plan.
rule 51		Fifth Stage: The entrances have no vestibule.

Figure 6- 32: Shape grammar rules for Tuyserkan congregational mosque in details

Zanjan Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A6		Second Stage: In this stage, 4 sides have been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to each side.
rule 32 & 31		Third Stage: In this stage, one of the eivans has gonbad-khaneh, but the others do not.
rule 4A5		Fourth Stage: Three sides have been chosen for the entries.
rule 4B5 & 4B8		Fourth Stage: One entrance has been added to the each chosen sides.
rule 51 & 52		Fifth Stage: The two entrances have vestibule, but one does not.
		As it was discussed in the previous chapter, some of the spaces of this mosque around the courtyard have been altered and are used as chambers.
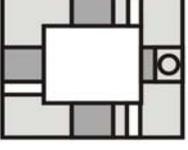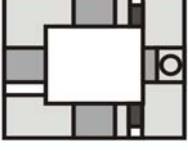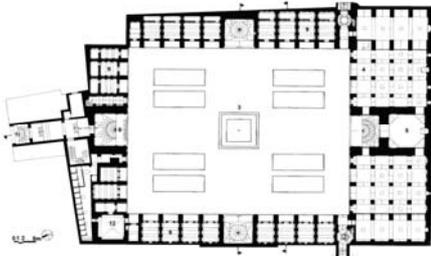
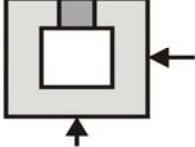**Figure 6- 33: Shape grammar rules for Zanjan congregational mosque in details**

6.2.17 *Zanjan Congregational Mosque*

This plan is the famous four-eivan type and its complex plan has been built by ten shape rules.
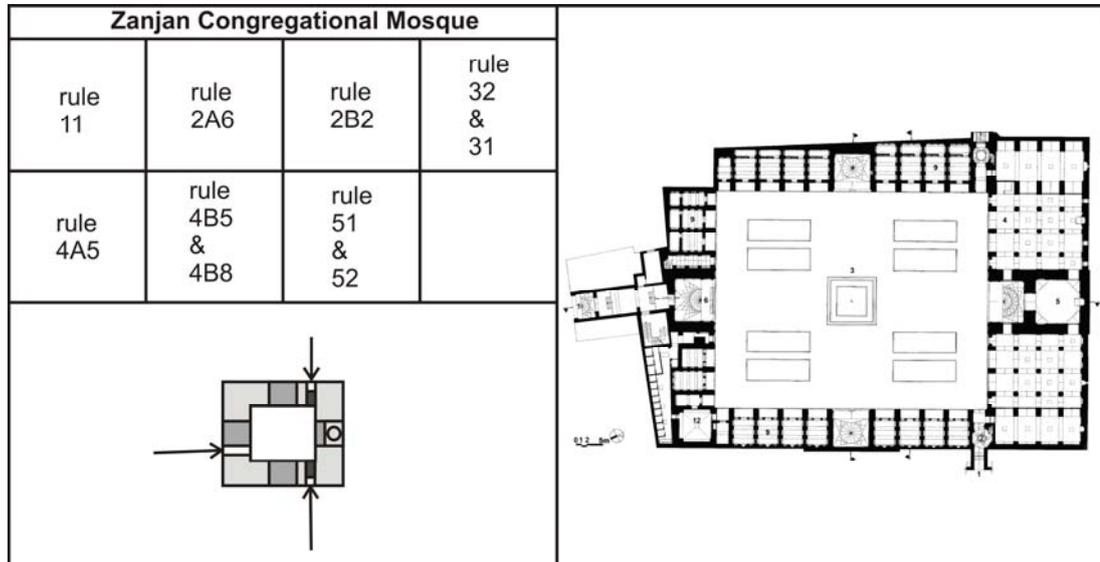
Figure 6- 34: shape grammar rules for Zanjan congregational mosque

6.2.18 *Zavareh Congregational Mosque*

This plan is the four-eivan type too. But it has a simple layout. In this analysis, space 7 is not included, because it has no function in the mosque.
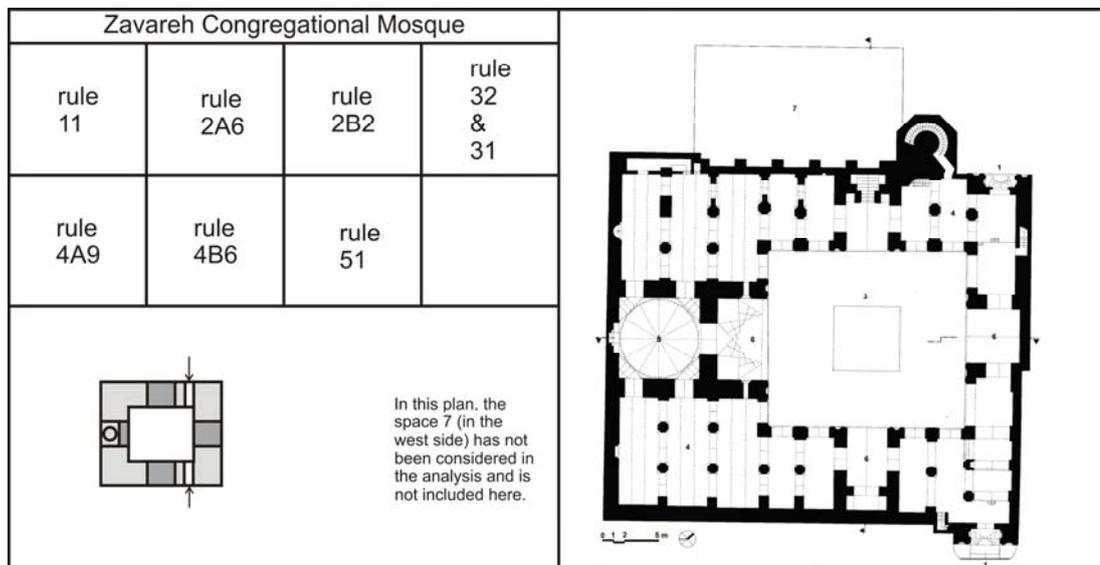
Figure 6- 35: shape grammar rules for Zavareh congregational mosque

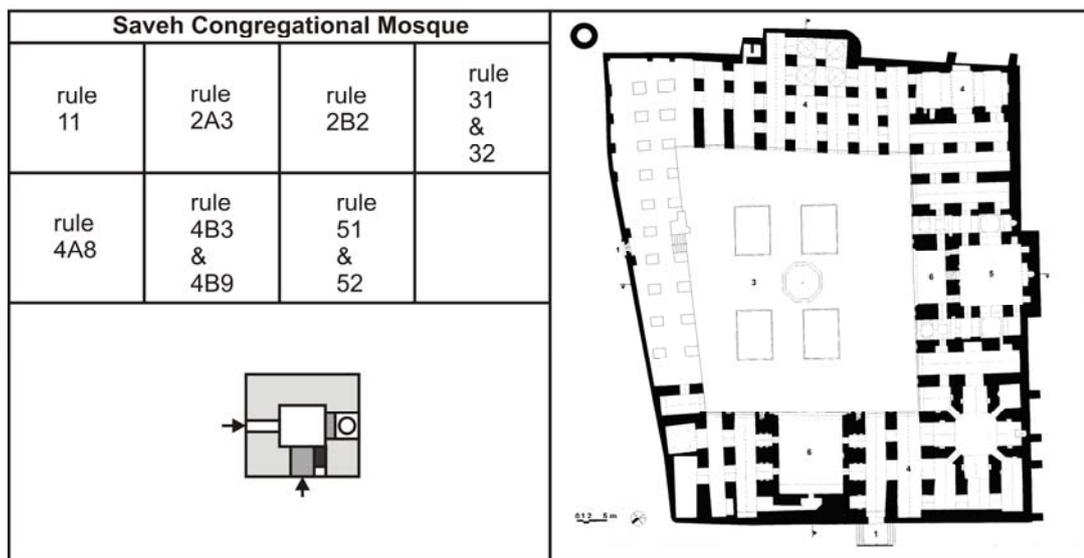| Zavareh Congregational Mosque		
Rule	**Derivation**	**Explanation**
rule 11		First stage: In this stage prayer hall and courtyard are defined.
rule 2A6		Second Stage: In this stage, 4 sides have been chosen for the eivan.
rule 2B2		Second Stage: One eivan is added to each side.
rule 32 & 31		Third Stage: In this stage, one of the eivans has gonbad-khaneh, but the others do not.
rule 4A9		Fourth Stage: Two sides have been chosen for the entries.
rule 4B6		Fourth Stage: One entrance has been added to the each chosen sides.
rule 51		Fifth Stage: The two entrances have no vestibule.
		In this plan, the space 7 (in the west side) has not been considered in the analysis and is not included here.
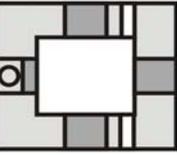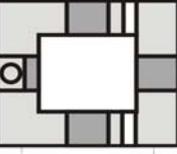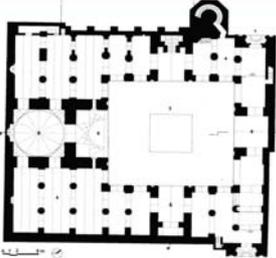
Figure 6- 36: Shape grammar rules for Zavareh congregational mosque in details

6.3   Results of Implementation

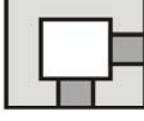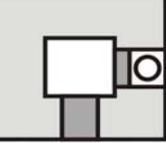This chapter draws on the previously defined Persian mosque grammar in chapter five in order to verify it. The grammar addresses the plan layout of Persian mosques and breaks down the geometry of the mosque plans into its constituent parts. In current chapter, this grammar was used to analyse these plans individually. This provides the basis for classifying mosques in terms of the properties of the sequences of rules applied to generate their plans. Besides, it is also used to distinguish different stylistic features in the mosque plans. Here, the Persian mosque grammar is interpreted both, by pointing to the rules used to derive different plan designs and by explaining the basic compositional features of different types of mosque plans.

6.3.1   Shape rules

Persian mosque grammar was successfully applied to produce all of the eighteen mosque plans in this chapter, therefore it verifies the Persian mosque shape grammar introduced in the previous chapter. This grammar through shape rules makes the design of Persian mosques more understandable and easily explainable. These findings are explained here.

As shown in Figure 6- 38 and Figure 6- 39, the most used shape rule is 2B2 which has been applied 16 times. This reveals that most of the mosques have one big eivan at least in one side of their plans facing the courtyard, except in two cases: Damghan and Sarab congregational mosques.

But surprisingly, the most common way of arranging an eivan is by locating it in one side of the courtyard, as rule 2A2 (Figure 6- 37) shows, rather than what historical documents suggest (Pope, 1965). Therefore, this study shows for the first time that one eivan is a common feature in the design of Persian mosques, rather than the famous four-eivan which has been suggested before. In this analysis, rule 2A2 which defines the one-eivan mosque design has been used 9 times, more than any other rule in the definition of the eivan in the mosque design.

Moreover, the popularity of rule 2A2 proves that the eivan is the most important element in the design of Persian mosques. This theory is supported by the rule 2A1 (Figure 6- 37), which introduces no eivan for the plans. As shown in Figure 6- 38, this rule has not been used in any of the case studies. In short, most of the mosques are one-eivan style (defined by the rule 2A2), while all of them posses at least one eivan (defined by the shape rule 2A1).
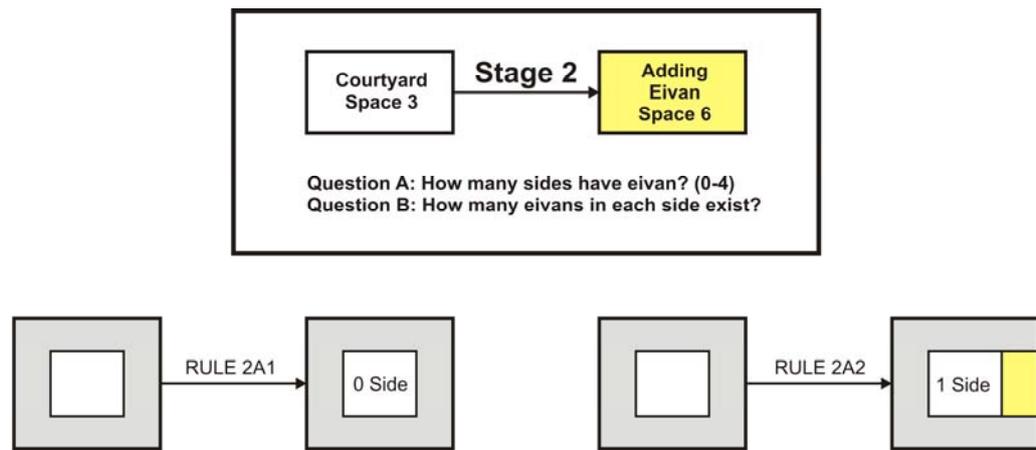
Figure 6- 37: In the first part of stage two, the number of the sides that eivan is needed is decided upon. It was discussed here that the rule 2A2 is the most common rule in the Persian mosque design contrary to what historical documents (Pope, 1965) suggests.

Shape Rules	Congregational Mosques																	
	Abhar	Ardestan	Babol	Boroujerd	Chaleshtor	Damghan	Dezful	Orumiyeh	Oshtorjan	Sabzevar	Sanandaj	Sarab	Sari	Saveh	Tabriz	Tuyserkan	Zanjan	Zavareh
11		●	●	●	●				●	●	●		●	●			●	●
12						●		●										
13																●		
14	●																	
15																		
16							●								●			
17																		
18												●						
2A1																		
2A2	●		●	●		●		●	●			●	●		●	●		
2A3							●							●				
2A4					●													
2A5										●								
2A6		●									●						●	●
2B1																		
2B2	●	●	●	●	●		●	●	●	●	●		●	●	●	●	●	●
2B3						●												
2B4											●							
2B5						●					●							
2B6											●							
31		●				●	●			●	●	●	●	●	●	●	●	●
32		●	●	●	●				●	●				●			●	●
33	●				●			●										
4A1											●	●						
4A2	●						●											
4A3										●								
4A4		●																
4A5																	●	

Figure 6- 38: First part of Persian mosque shape grammar rules to produce the case studies.

Shape Rules	Congregational Mosques																	
	Abhar	Ardestan	Babol	Boroujerd	Chaleshtor	Damghan	Dezful	Orumiyeh	Oshtorjan	Sabzevar	Sanandaj	Sarab	Sari	Saveh	Tabriz	Tuyserkan	Zanjan	Zavareh
4A6											●							
4A7												●						
4A8								●	●				●	●				
4A9			●	●	●	●									●	●		●
4B1																		
4B2											●	●						
4B3														●				
4B4																		
4B5		●	●	●	●			●	●								●	
4B6				●		●							●		●	●		●
4B7									●									
4B8																	●	
4B9								●					●	●				
4B10					●													
4B11															●			
4B12		●								●								
51	●				●	●	●	●	●	●				●	●	●	●	●
52		●	●	●	●			●			●	●	●	●			●	

Figure 6- 39: part of Persian mosque shape grammar rules to produce the case studies

As was discussed in the chapter two, the courtyard is another important element of Persian mosque plans. The courtyard is often located in the middle of the plan surrounded by other spaces. The analysis of shape grammar rules in this chapter supports this theory and reveals that rule 11 (Figure 6- 40), which locates the courtyard in the middle of the plan, has been used 11 times in total, more that other shape grammar rules in the stage one.
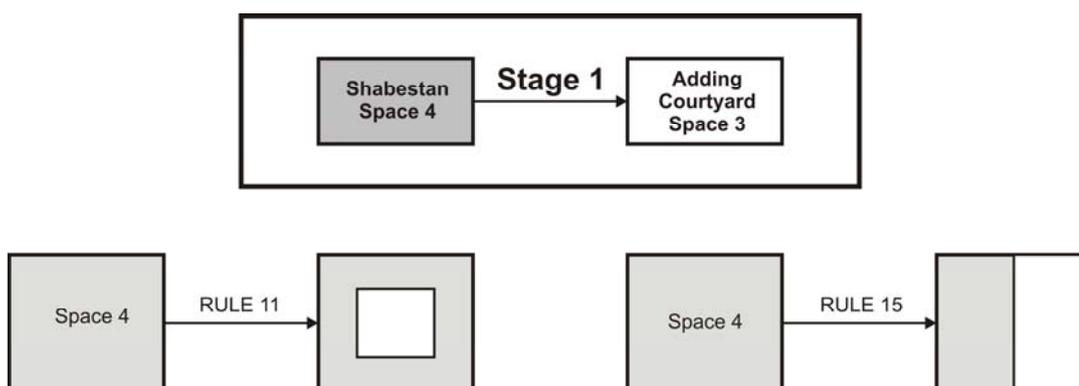
Figure 6- 40: The first stage of Persian mosque shape grammars. It starts with the space 4 or initial shape and then space 3 or courtyard is added to. Here was discussed that rule 11 has been used 11 times more than other rules from this stage.

Majority of the mosques have more than one entrances. Ten mosques have entrances in two sides of their plan and two mosques have even entrances in three sides. However, this characteristic was predictable as the mosques have segregated spaces for men and women, thus it is preferred to have at least two entrances for this reason.

These findings demonstrate the importance of shape grammar sequence and rules. These conventions that govern the arrangement of spaces on these plans have some requirements. Because the first rules separate different mosques types, but later they become more detailed and therefore carry less information for analytical purposes, and at the same time, become more precise and better for generative purposes. Thus in order to formulate an analytical grammar, the primary spaces should be allocated first and then the location of the secondary spaces.

In this research, these primary spaces were distinguished by their functions, such as prayer hall or shabestan which places the main function of the mosque; or by their size, such as courtyard which is bigger than other spaces and is occupied over longer periods of time. For secondary spaces, the shape rules were grouped to give them more analytical ability. These groupings were used in defining eivan and entrance, when the analyiser has to decide how many sides the element is applied to. And then s/he chooses how many times apply the rule.

Finally, the examples given here demonstrate the potential of the shape rules for comparing and constructing Persian mosque designs. This implementation shows the similarities in the rules used to construct some plans which have no observable similarities in composition, such as the use of rule 2B2 in 16 different mosque designs. Therefore, the present implementation, from the analytical point of view, portrays the Persian mosque designs in a subtle and more precise way than other existing descriptive sources. It differs from these literatures, as it is based on formal specifications of Persian mosques and not on visible appearance of designs.

6.3.2   *Persian mosques*

It was showed here that the establishment of courtyard is important to the definition of Persian mosques and other spaces are formed around this space. Based on this factor, there are six different forms for Persian mosques, produced by rule 11, 12, 13, 14, 16 and 18. There was no case study that uses rule 15 (this rule defines the plan with a mass in one side and a courtyard in the other side) or rule 17 (this rule locates the mass in the middle of the courtyard). These two rules are useful when shape rules are used to produce bigger and therefore more complex mosques.

Once a courtyard is established, an eivan is the centre of Persian mosque design. In the next level, most of the mosques have one eivan in one side of the courtyard. However, the cases which have more than one eivan are more common than without any eivan. Thus, one eivan is the most repeated characteristics of Persian mosques.

The basic composition of the mosque design includes a gonbad-khaneh too. In all of the cases, gonbad-khaneh is located next to eivan. However in two cases, Abhar and Dezful congregational mosque, there is only one gonbad-khaneh without an eivan.

The process described up to this point defines the core structure of the mosque and the entrances are the next elements in the grammar. Only few mosques have one entrance; Dezful, Saveh, Sarab, and Sanandaj; while twelve mosques have entrances in at least two sides of their plan.

The basic compositions produced here shows that vestibule is not a defining feature in the mosque design. Twelve entries do not have vestibule, while nine entries have it.

Finally, this implementation demonstrates and explains the characteristics of each Persian mosque plans through a grammar which is not only correct, since it produces designs with the desired outcome, but also convincing, since its rules are remarkably simple but manage to explain the essential and the most general features of the case studies.

Moreover, this grammar provides a promising method for the classification of Persian mosque plans. It is not only precise as was shown here, but is also flexible and by no means restricted to other factors, such as climate, material, and so on. The method employed here is flexible and general enough to be applied to larger and more diverse samples of plans.

6.4   Summary

The Persian mosque grammar breaks down the plan of mosque to its constituent parts and therefore allows these parts to be analysed individually. In this chapter, the accuracy of this shape grammar was verified. In other word, the Persian shape grammar introduced in the previous chapter was used to reproduce the plans of the

eighteen case studies. And it was shown through this implementation that this formalism is general enough to include different types of mosques while reveals different characteristics of Persian mosques.

Chapter 7: Conclusion

7.1   Introduction

This chapter summarises the main arguments of the previous chapters and gives some recommendations for future research on Persian mosques and shape grammars.

7.2   Conclusion

It was discussed that congregational (or jame) mosques are the most important types of building in Islamic countries that served as the principal social and ideological centres in towns and cities. The mosque is the only specific architectural form that Islam has introduced. Each region of Islam has created an architectural image of its own, based on local material, craft skills, climate and other factors. Persian architecture has continuity and a style of its own too. In addition to the influence of climate, available material, religious purpose and peripheral cultures, the patrons have also played an important role in this architecture. However, some certain elements of Persian mosque design have persisted through the time, such as interior court, pool, and the angled entrance.

There are three formative stages of mosque design in Persia. In the first stage, the mosque form was a hall with an open courtyard surrounded by walls; the second

stage was more complicated style; and the third stage is characterised by the use of monumental scale in the sixteenth century. In general, the Persian mosque is simple and the only central idea in it is communication with the God. In the mosque design, rules of geometry are applied in a flexible manner and are used to provide general guidelines rather than lay down specific rule and no direct relationship between the architectural form and the function in the mosque design can be seen.

As was mentioned in chapter three, the history of the Persian mosque designs have been studied before. Detailed historical accounts on the extent and the variety of works are given by Pope (1965), Frishman (1994), Haji-Qassemi (1996, 1998, 2004a & 2004b), and Yarshater (2006). However, these attempts have been partial satisfaction and the only existing classification for mosques is based on their size and importance. And none of these sources tries to categorise Persian Mosques in the more comprehensive way.

It was discussed that shape grammars formalism has been successfully used to describe and analyse past or present designs, as it has some unique characteristics that make it suitable for analysing purposes. Shape grammar analysis creates objective and dynamic classes, as they are based on spatial information. Another advantage of using shape grammars for categorisation is that not only it analyses existing body of designs, but it also create a structure that supports the need of the designers too. The basis of using shape grammar was the idea of capturing the knowledge behind Persian mosques designs.

In chapter four, the criteria for the case studies were discussed and based on them eighteen congregational mosques plans were chosen. They are within the current borders of Iran, built between 661 and 1935. The study was restricted to the analysis of the first floor plans of these one-storey mosques.

In chapter five, the chosen Persian mosque plans were studied in the terms of their circulation patterns with special consideration about the characteristics of different

spaces within the plans. These circulation diagrams suggest specific patterns in the plans and show the relationship between important spaces. It resulted in defining and grouping different spaces of the mosque plan. Generalisation about these findings was not difficult, as a large number of samples provide a good average for doing so.

This study of Persian mosque plans revealed four simple recurring characteristics: (1) qebleh: it is a wall in the prayer hall which faces Mecca and all prayers are directed towards it; (2) segregation of men and women in the mosque; (3) use of courtyard: Persian mosques have at least one courtyard which is an open space surrounded by walls with a pool in the middle of it; and (4) high connectivity between some spaces: there are high connectivity between some single, independent spaces in the plans which if both appear in a plan, they are always found together; they are (a) eivan and gonbad-khaneh; and (b) entrance and vestibule. These findings are simple compositional ideas and are important for shape grammar development.

The shape grammar development in this chapter began with finding simple recurring formal elements from the plans, exploring the spatial relations between these elements, elaborating a sequence in which these shape rules can be applied in order to generate various mosque plans, and at last expressing characteristics of plans in the elements and the spatial relations in the shape rules.

Later, Persian mosque grammar was illustrated. It includes five stages and the initial shape is prayer hall or shabestan. These stages which include two group blocks are: (1) defining courtyard or space 3; (2) defining eivan or space 6 (part one of block A); (3) defining gonbad-khaneh or space 5 (part two of block A); (4) defining entrance or space 1 (part one of block B); (5) vestibule or space 2 definition (part two of block B). The results of applying these rules are simple one-courtyard plans. The next groups of rules were introduced to produce mosques with more than one courtyard or irregular shapes.

In chapter six, the Persian mosque plans were analysed and described by shape grammar rules which distinguished certain characteristics common to them. This grammar breaks down the geometry of the plans into their constituent parts and allows them to be analysed individually. Based on this grammar, a constructive description of each case study was presented. It includes a set of operations by which the plan can be produced from the initial shape.

As was discussed in detail in the previous chapter, the analysis showed that courtyard is an important element in the Persian mosque plans. All of the case studies have at least one courtyard and they have strategically located after the entrance/vestibule, and before the prayer hall, in order to emphasise the façade and the process of entering the mosque for prayers. Another important element of Persian mosque plan is shabestan, a specific form of prayer hall. The relation of courtyard and shabestan (or prayer hall) is the most important factor in the design of Persian mosques. It was discussed that eivan is the most common feature in the Persian mosques and most of the mosques have more than one entrance.

This characterisation (Stiny & Mitchell, 1978b) verifies the Persian mosque grammar, as: (1) it clarifies the underlying commonality of Persian mosques; (2) it supplies the conventions and criteria to determine whether a building is in a type; and (3) it provides the compositional machinery needed to design mosques. All of these were demonstrated through the Persian mosque implementation in chapter six.

Therefore, the Persian mosque grammar provides a promising classification for Persian mosques which is rigorous and at the same time flexible and by no means restricted to other factors, such as climate, material, technique of construction and so on.

7.3   *Recommendations for future research*

The current study was aimed to study and classify Persian mosque plans, thus it was restricted to the analysis of the first floor of one-storey mosques. However, other

aspects of their architecture, such as their forms and facades were not discussed here. Besides, the increasing differentiation of functions within the plans of bigger two-storey mosques can result in a greater complexity of plans which can be the topic of another research.

In the preceding chapters, Persian mosques were studied by the means of shape grammars and their plans were analysed by the grammar. This grammar is a very useful aid for designers and scholars. It helps with analysis as well as providing a great level of flexibility in designing. Designing a mosque is difficult not only because of its unique form, but also because of producing a correct circulation patterns. This grammar can also be used to produce the correct plan with great flexibility. In other words, only the analytical application of this grammar was discussed here and the generative qualities of it for potential mosque designs was not described. This grammar can be used as a design tool by which new plans are developed based on a desired type. These plans can be customised to the requirements of the architects for producing new plans, but will be in the given type. Moreover, the prototypes produced in chapter five can also be used for computational purposes too.

However, by using these grammars new and original designs can also be built. Knight (1980) has mentioned that a simple method for defining new spatial relations from the existing ones consists of replacing one or more shapes in the given spatial relation with another shape which may or may not be in the given spatial relation. This shape replacement operation is a powerful tool for creating new and original languages of designs from existing one. In this way, the Persian mosque rules can be employed to construct quickly and effortlessly a multiplicity of new languages of designs for Persian mosques. In this context, Persian mosque rules and the classes are means for producing new languages of designs.

Finally, this grammar showed the advantage of shape grammar formalism. However, this classification system is not complete and a comprehensive analysis, for example,

a comparison of regional variations or of changes over time within a region, and their relation to prevailing or evolving patterns of technological, environmental, social, and economic conditions can be the topic of next research.

7.4 *Summary*

In this research, a shape grammar for Persian mosque was developed. This grammar broke down the geometry of the given plans into their constituent parts and allowed these parts to be analysed individually. This shape grammar supplied each plan under consideration a constructive description, that is, a set of operations by means of which the plan could be generated from the initial shape. The shape rules and the classes they defined were the basis for a rigorous and substantial analysis of the formal composition of Persian mosque designs. Moreover, they were used for reproducing the plans. The result provided a classification of Persian mosque plans which is not only precise, but also flexible and by no means restricted to other factors, such as climate, material and so on.

As it was mentioned, this grammar illustrated that the shape grammar formalism is general enough to study design conventions independent of their geometric realisation. However, it needs to be recognised that no classification system can reflect accurately all aspects of architecture and there are always multiple ways for communicating knowledge, thus there can always be ambiguity in any categorisation. Observed differences and similarities within these mosques provide a first step towards a comprehensive analysis.

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