ABSTRACT

IN SEARCH OF THE LOST GARDEN ATMOSPHERE WITHIN THE COURT OF THE LIONS: A LANDSCAPE ARCHITECTURAL PERSPECTIVE

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The Court of the Lions has been known for its architectural beauty which is universally admired. However, a closer look at the current gravel-surfaced Courtyard does not seem to harmonize with the pinnacle in architectural representation of its surrounding and the once “state of the art” technology of the fountain at the centre. According to The Official Guide - The Alhambra and Generalife published by the Petronato de la Alhambra y Generalife (1999, p. 115), "...It is not known for certain whether the four parts were paved or if they were gardens". This uncertainty became the catalyst for this Grounded Theory landscape architectural research which employs concept mapping techniques. Computer concept and illumination models were then used to test a design concept through a series of simulations. Lastly, the possible landscapes were interpreted using photorealistic computer images and animations, re-enacting the original garden atmosphere in the year 1391 AD. The study describes the process to simulate the garden atmosphere of the Court of the Lions with the absence of primary sources of information. The approach can be used for other historic sites in similar site condition.
ACKNOWLEDGEMENTS

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I must also acknowledge Illustration Magic Inc. which provided substantial funding, high end computers and software to see this research realized.

To my classmates, I thank you all for the memories and support throughout our time together, and most importantly our friendship.

Finally, I wanted to express my love and thanks to my family and friends. Thank you all for the continuous support, especially my parents and my wife Sofia, in so many ways. I am speechless to the overall excitement and experience of this study.
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Also:

7 Photorealistic computer images showing the possible garden atmosphere within the Court of the Lions in 1391AD
It has been my vision to unite the art and science of landscape architecture with high tech computer 3D visualization technologies. My first use of the technology dated back to 1991 in the final year of my undergraduate degree in landscape architecture. The continuing realization of the importance of the use of technology has sustained my interest in staying current with the technology while practicing in the field of landscape architecture since that time. With more than ten years of professional practice, I have developed specialized techniques and expertise in computer visualization technology. With this design passion in landscape architecture and the love of technology, my current master’s research has provided the perfect opportunity to realize my vision to use landscape architectural analysis with the extensive use of computer visualization technology as a virtual test instrument and as a final presentation tool. Without these virtual approaches, this research simply could not have been performed.
People from different religions, namely Christians, Jews and Muslims, enjoyed more than eight hundred years of prosperity, peace and culture for almost eight centuries (711-1492 AD) under the Islamic government of Andalucia, the Islamic Spain (Scurr, 1991). The word Andalucia came from the Arabic word Al-Andalus. It referred to “the whole area of the Iberia peninsula under Muslim dominion” (Fernandez-Puertas, 1997a, p. 3). It was the peacefulness of the multi-cultural and multi-religious society which allowed people to focus on their work and to expand their intellectual explorations to new heights. Architecture, gardens, engineering, medicine, navigation, astronomy, mathematics, textiles, agriculture were some of the fields where unprecedented accomplishments were attained. Many of the resultant achievements have benefited the world ever since.

“… It was [Islamic] leadership based on meritocracy, not inheritance. It was leadership that harnessed the full capabilities of a very diverse population – that included Christianity, Islamic, and Jewish traditions. This kind of enlightened leadership — leadership that nurtured culture, sustainability, diversity and courage — led to 800 years of invention and prosperity…”

(Fiorina, 2001)\textsuperscript{1}

\textsuperscript{1} Carleton Fiorina, Chief Executive Officer of Hewlett Packard.

\textsuperscript{2} Fernandez-Puertas commented that the designation of the region of Iberia peninsula should not be confused with the modern and much smaller geographic region of Andalucia, although its name derived from it.
The Court of the Lions is located within the Alhambra complex in Granada (Figure 1). The name Alhambra comes from an Arabic root which means “red” (al Qal‘at al-Hamra, red castle) (Grabar, 1978; Rabbat, 1985; Villa-Real, 1981). The complex sits on top of the Sabika Hill, between the rivers Darro and Genil (Bermudez Lopez & Galera Andreu, 1999). The construction of the Alhambra complex stretched from 11th to 15th century through stages of development (ibid). The Court of the Lions is acknowledged as a prime example of design achievement built during the most brilliant period of the Nasrid Dynasty (1238-1492 AD) at the peak of the Islamic dominance of the region (Ruggles, 2000).

Due to the historic and cultural significance of the complex, Alhambra was declared a national monument in 1870 (Villa-Real, 1981) and was designated a UNESCO world treasure in 1984 (Van Zuylen, 1999).

![Figure 1: The Alhambra complex](Source: Grabar, 1978, p.31; edited by the researcher)
Figure 2: Palace and Court of the Lions in relation to other Nasrid Palaces
(Source: Ruggles, 2000, p. 183; edited by the researcher)

The Court of Lions is located at the centre of the Palace of the Lions (Figure 2 and Figure 3). Built between 1370 and 1390 (Ruggles, 2000) for Sultan Mohammad V (Bermudez Lopez & Galera Andreu, 1999), the Palace represented a synthesis of all stages of the Alhambra development (ibid). The Courtyard is surrounded by beautifully-decorated arcades, slender white marble pillars with the Fountain of the Lions located in the middle. Although the geometry of the Courtyard is laid out according to the universal Islamic garden
symbol of the *Chahar Bagh*³ (Van Zuylen, 1999), a garden quartered by two intersecting water channels (Alemi, 1986) at right angles to each other with a central pool (Van Zuylen, 1999), the current graveled state falls short of the expected Islamic configuration. Traditional Islamic garden design principles

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³ *Chahar Bagh* is a Persian word (Brookes, 1987). *Chahar* means “four”, *Bagh* means “garden” (Clark, 2004).
dictate an anticipated abundance of plants with scent, fruits and colours as a “required” design component in Islamic garden design theology (Clark, 2004). The current over-simplified graveled Court of the Lions (Figure 4) with solitary orange shrubs located at each corner of the Courtyard simply does not harmonize with the pinnacle in architectural representation of the courtyard surrounding and the once “state of the art” hydraulic technology of the fountain. Furthermore, according to Professor Antonio Fernandez-Puertas, the entire Palace layout was dependent on the layout of this particular courtyard (Fernandez-Puertas, 1997a). In his book, the Alhambra expert revealed the possible stages of the design development of the Palace layout extended from the geometrical arrangement of the Courtyard. This not only shows the importance of the Courtyard, but its inseparable relationship between the Palace and the Courtyard through the use of geometry. These incongruencies became an indirect curiosity to the researcher that the Court of the Lions may have a deep
meaning and configuration which goes beyond its current simple graveled representation.

“This Palace [of the Lions] represents the culmination of architectural manifestations for a people whose taste reached a high degree of sensibility due to the considerable economic prosperity, and the long evolution of Hispano-Islamic art from early periods.”

(Rabbat, 1985, p. 64)

The search for the description of the original garden of the Court of the Lions is challenging due to the complete absence of primary sources of information about the garden during Mohammad V’s period. James Dickie commented that not even a vestige of the original faience\(^4\) survived in the Court of the Lions (Dickie, 1992). The difficulties in obtaining information about the original garden will be explained in details in Section 2.2 Research Difficulties and Limitations.

The present gardens of Alhambra and Generalife reflect the horticultural tastes of Spain in the 1920s, rather than medieval realities (Irwin, 2004). As well, according to The Official Guide - The Alhambra and Generalife published by the Alhambra Authority, Patronato de la Alhambra y Generalife in 1999, “…It [The Court of the Lions] was not known for certain whether the four parts were paved or if they were gardens”, (Bermudez Lopez & Galera Andreu, 1999, p. 115).

While there has been extensive research on the architectural elements within the

\(^4\) Also spelled Faience, or Fayence. It is tin-glazed earthenware made in France, Germany, Spain and Scandinavia. Cited in Britannica Online Encyclopedia (http://www.britannica.com/eb/article-9033566/faience)
Courtyard, personal communications with Professor Jose Tito-Rojo\(^5\) and Professor Fairchild Ruggles\(^6\) confirmed that there has not been any systemic archeological excavation within the Courtyard. It was this historical mystery which became the catalyst and driving force for this Grounded Theory landscape architectural research. Concept mapping techniques were employed to rationalize possible conjectures regarding the Courtyard’s original landscape elements. This thesis describes a method of exploring historical configurations of this famous landscape virtually. Computer 3D concept models and illumination models of the Courtyard served as virtual test instruments to test a design concept through a series of simulations. The possible Courtyard environment was interpreted using photorealistic computer images and animations, with the object of re-enacting the atmosphere of the original garden and surrounding structure created during the 2\(^{nd}\) reign of Sultan Mohammad V in 1391 AD.

2.1 RESEARCH IDENTIFICATION

Although visitors have admired the architectural beauty of the Court of the Lions, a closer look at the current graveled Courtyard reveals a mismatch of spatial, aesthetic, spiritual aspects of the garden and an incongruency between the architecture and the landscape. The Islamic garden is considered as an extension of the living space of architecture (Irwin, 2004). The garden-architecture relationship is so intimately entwined that the separate components

\(^5\) Email correspondence dated February 9, 2006; Professor in Departamento de Botanica, Facultad de Farmacia, Universidad de Granada, Spain

\(^6\) Email correspondence dated February 21, 2006; Associate Professor in Department of Landscape Architecture, University of Illinois, U.S.A.
are seen as part of one single composition (Van Zuylen, 1999). Though the perfection of integration between architecture and garden was well practiced in the courtyard designs of Andalucia (Abdine, 1986), this spatial relationship is not present in the current Court of the Lions. The complete void of the Courtyard does not have the spatial quality to “entwine” with the architectural elements to become one continuous space. The expected continuity of the spatial relationship between the garden and the architecture has been eradicated. The spatial relationship will be further explained in Section 2.3.1 Evidence from spatial analysis of garden-architecture relationship.

Aesthetically, the current simple graveled courtyard with four orange shrubs does not harmonize with the intricate details of the architectural elements. Furthermore it does not reflect the creative engineering which brought water to the centrally located Fountain of the Lions and the rest of the Alhambra complex. A similar level of intricacy would have been expected in the planting design of the Courtyard complementing the art of architecture and the engineering endeavour.

Spiritually, plants have long been considered the second most important design element in Islamic gardens after the garden’s physical configuration (Clark, 2004). Shade, fruit, scent and colour of plants (Nassar, 2002) are used as constant reminders to believers of the presence of God by invoking the five senses (Clark, 2004) and the reward of the anticipated Paradise upon doing good deeds reflected in these spaces. As well, in Islamic gardens, the physical landscape elements have strong symbolic meaning as described in the Holy Quran (Clark, 2003). These sensations provide a touchstone for the sense of
paradise in this world (Blakstad, 1986). The current state of the Court of the Lions lacks this strong physical-spiritual relationship and symbolic content.

Furthermore, Islamic gardens reflect the idea of conservation in Islam (Gardens, Nature and Conservation in Islam, 2002)\textsuperscript{7}. Muslims treat nature with respect and deep gratitude to the beneficial Creator and Bestower (ibid). Hence in an Islamic garden design, the consciousness of preservation is always present. This ideal becomes a timeless design guideline across all Islamic culture in order to preserve and conserve the beauty of God’s creation. The current Court of the Lions does not seem to demonstrate the objective of conservation\textsuperscript{8}.

In summary, the current state of the Court of the Lions lacks the expected spatial, aesthetic, and spiritual aspects and conservation ethos of as an Islamic garden. The resultant garden atmosphere has been compromised. As it stands today the Court of the Lions seems an empty vessel which differs from what was possibly there during its prime and distant glory. This is the motivation for this in-depth research on the Court of the Lions.

2.2 RESEARCH DIFFICULTIES AND LIMITATIONS

The search for historical descriptions of Arab gardens contemporaneous with the creation of the Court of the Lions proves difficult. Firstly, these Hispano-Arab gardens, unlike their Perso- and Indo-Islamic counterparts, suffer from a lack of


\textsuperscript{8}Conservation has become an important issue in today’s world. The importance of this ideology has led UNESCO to initiate a proposal to establish a Quran Botanical Garden to achieve important objectives in the fields of environmental conservation, scientific research, education and recreation (UNESCO, 2005).
pictorial documentation. Reconstruction has to be based on surviving or excavated examples. This can be supplemented by period descriptions (Dickie, 1986), however they should be cautiously used because of possible misinterpretations of the cultural and religious contexts. In 1831, Richard Ford, an English travel writer who stayed in Alhambra, mentioned that the description of the Alhambra was too dependent on the description of the Western visitors (Irwin, 2004). We have to remember that Western visitors at the time had limited knowledge of Islamic culture. Subconsciously they may have used their own Western cultural knowledge to colour their findings. An example is the misconception or misinterpretation of the Palace of the Myrtles and Palace of the Lions as being two parts of the same palace (Dickie, 1992). This has been a misconception evolved through 140 years of Western scholarship (Rabbat, 1985).

There have been successive alterations and transformations imposed on the whole Alhambra complex over the five centuries since the Reconquista⁹ (Rabbat, 1985; Torre Lopez et al., 1996). During Arab Times the two palaces were originally two set of apartments, the ones centered around the Court of the Myrtles and the other around the Court of the Lions (Irwin, 2004). They were separate palaces standing back-to-back with a party wall between them (Dickie, 1992). The two Palaces were separated on the north by a street, which provided access to the furnace of the bath complex. Flanked by blank walls on either side, the street was designed in such a way as to prevent the servants who used it

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⁹ *Reconquista* is a Spanish word which means “Reconquest”. It was a series of campaigns by Christian states to recapture territory from the Muslims, who had occupied most of the Iberian Peninsula in the early 8th century. Cited from Britannica Online Encyclopedia (http://www.britannica.com/eb/article-9062907/Reconquista)
from catching even so much as a glimpse of the occupants of the baths or those relaxing in the garden (Dickie, 1992). The current narrow passage linking Court of Myrtles and Court of the Lions (Figure 5) were not there in the Arab period (Casa Valdes, 1987). The two palaces were jointed together during the reign of Ferdinand and Isabella (Irwin, 2004). This passage has been used as a vital link in the new circulation system for today's visitors (Dickie, 1992).

Secondly, the original garden was probably removed shortly after the Reconquista. The Nasrid Dynasty went into decline throughout the 15th century. Within this period the Dynasty faced internal power struggles amongst the Royal family members as well as constant danger passed by the advancement of the Reconquista (Cabanela Rodriguez, 1992). This may explain why after the death of Mohammed V, there was hardly any construction work carried out within the Alhambra (Van Zuylen, 1999). The end of the Nasrid dynasty was slow and

Figure 5: Original service access and new circulation (Source: Enlarged from Figure 2; edited by the researcher)
inevitable which marked by the fall of Granada (Van Zuylenn, 1999). The constant attention to the power struggle and the war against the Reconquista helped to explain why in 1492, after the surrender of the last Muslim Sultan Boabdil to the Christian monarchs Ferdinand and Isabella of Spain (Jay, 1931), a number of Muslim craftsmen were recruited to renovate the Alhambra because it had been sadly rundown (Irwin, 2004). In fact, it was highly possible that the original Arab garden within the Court of Lions was completely removed during this 1492 renovation because of the garden's poor condition as well as the possible purpose of “erasing Islamic history” (Nuere, 1986, citing D. Leopoldo, p. 92) after the Reconquista. This action would have run parallel with the “joining of the two palaces” mentioned earlier as well as with a series of other destructive actions that took place during that time period. For example, the expulsion of Jews and Muslims in 1492 and 1502 respectively (Van Zuylenn, 1999); and the burning of “a veritable mountain” (James, 1972, p. 2) of Arabic manuscripts in the main square of Granada organized by Cardinal Ximenez de Cisneros after he became the Archbishop of that city in 1499 (Irwin, 2004). This destruction of Arabic manuscripts and the expulsion ensured that surviving literary sources of this civilization and its occupation of this region would be scanty or non-existent (Dickie, 1986). Richard Ford commented that the destruction of the Palace started in 1492, for the "injuries began that very day after the conquest when the 'purifications' of the monks, that is the whitewashing and removals of Muslim symbols, commenced" (Irwin, 2004, p. 145)\textsuperscript{10}.

\textsuperscript{10} Irwin cited Ford R. (1845) \textit{A Handbook for Travellers in Spain}
Thirdly, confounding is the fact that all surviving European visitors’ descriptions of the Court of the Lions that took place after 1492, are not consistent with one another. These range widely, variously including accounts of the garden as a full marble-covered courtyard to a squared off space containing six orange trees (Irwin, 2004). Jeronimo Munzer was the first recorded visitor to visit Alhambra in 1494, a hundred and three years after the completion of the Palace of the Lions during Mohammad V’s time. These descriptions of the courtyard may be true to the European visitors’ own corresponding era, but may not necessarily reflect the original garden atmosphere during the Nasrid period of Mohammad V. These descriptions from the European visitors will be discussed in more detail in Section 3.1 Research Evolution.

Fourthly, there have been great difficulties in tracking plant use due to a series of events. In Andalucia many of the best Moorish gardens “disappeared along with much else that was oriental soon after the Christian conquest” (Stapley & Byne, 1923, p. 491). Almost simultaneously, the European contact with the New World\textsuperscript{11} in 1492 by Christopher Columbus (Van Zuylen, 1999) has altered the flora of Europe and led to the introduction of exotica on an unprecedented scale (Dickie, 1986; Segall, 1999). With the breakdown and disuse of the eight hundred years of comprehensive irrigation system devised by and maintained under the Moors\textsuperscript{12} after their expulsion from Spain, the Islamic gardens of the Iberian peninsula “almost all decayed and died” (Lehrman, 1980, 11 It was know as the “discovery” of America.
12 The Muslims who arrived and settled in Al-Andalus were called “Moors”. It was a negative term referring to the people who came from Morocco. They themselves, however, did not use the term to refer to themselves (Beig, no date).
p. 91). As well, the Italianization of palaces and gardens under Renaissance influences erased the original Islamic tradition in less than one hundred years (Dickie, 1986). Furthermore, there have been few data on the original layout of Alhambra gardens (Bermudez Pareja, 1973). The exact planting is not known today and probably will not be learned until that day that paleoarchaeological techniques such as seed flotation are employed (Dickie, 1986; Ruggles, 2000). However it is questionable how useful such techniques would be in these gardens since they were replanted in the centuries after the Reconquista by patrons with very different horticultural tastes (Dickie, 1986; Ruggles, 2000).

Finally, as mentioned earlier the present Alhambra Authority, Patronato de la Alhambra y Generalife, does not claim any assurance as to the composition of the Courtyard at its Islamic height: “it was not known for certain whether the four parts were paved or if there were gardens” (Bermudez Lopez & Galera Andreu, 1999, p. 115). This statement from the Alhambra Authority confirms the uncertainty of the original Court of the Lions.

2.3 ORIGINAL GARDEN EVIDENCES

From a landscape architectural perspective, a considerable amount of evidence supports the presence of a more elaborate garden within the Court of the Lions than is found today with the simple Chahar Bagh configuration. The following outlines the key evidence which covers a variety of sub topics including architectural, archaeological and poetics aspects:
2.3.1 Evidence from spatial analysis of garden-architecture relationship

The Palace of the Lions was created as an escape for occupants of Alhambra from the rigid constraints of court life and used as a villa urbana (Dickie, 1986). According to Dickie, a villa in the heart of the city cannot have a serious purpose other than for pleasure and therapeutic purposes (Dickie, 1992). The Courtyard was designed to emulate the conditions of the picturesque rural environment (Rabbat, 1985). Dr. James Dickie's spatial analysis of the Palace of the Lions describes the complex consisting of two gardens: the Courtyard garden and a lower but now vanished garden (Patio de Lindaraja). These two gardens were linked to the opposite ends of the Hall of the Two Sisters (Figure 6). Hence the Hall had separate vantage points overlooking the two gardens. One side opened to the view of the inner Courtyard while the opposite side overlooked the lower garden which led the eyes of an observer to the natural landscape beyond by means of a maridor (window) known as the Maridor of the Lindaraja. These two gardens were pleasure gardens arranged for sensuous people, and for very

\[\text{Figure 6: Physical relation between Palace of the Lions and the two gardens (Source: Ruggles, 2000, p. 201)}\]
earthly purpose (Rabbat, 1985) of relaxation. The Hall of the Two Sisters is the most pleasant space in the Palace, reserved for Sultan Muhammad V (Dickie, 1979; Van Zuylen, 1999).

2.3.2 Archaeological Evidence

A key piece of physical evidence was unearthed in 1902. An excavation carried out by architect Cendoya within the Courtyard took place during the stabilization of the surrounding structure’s foundations. During the dig, archaeologist Manuel Gomez-Moreno witnessed the original Arab soil level which was discovered 80cm below the existing pavement level (Dickie, 1976; Irwin, 2004; Van Zuylen, 1999). It is worth noting that different Islamic geographic regions have different variations of garden style but all based on the universal Chahar Bagh garden layout (Van Zuylen, 1999). The sunken planting beds were the “regional variation” garden feature commonly used during the Andalucian period and were used as a water conservation method allowing better retention of water for plants in the hot climate (Clark, 2004). The sunken planting beds can be found in a number of gardens located within Cordovan, Almerian and Seville area (Dickie, 1976). Hence the sunken planting beds within the Court of the Lions suggested that they were used for gardening purposes.

“The architect Cendoya had the courtyard excavated in order to reinforce with concrete the foundations of the surrounding buildings, the stratification of the soil was upset; however, the late Manuel Gomez Moreno, who witnessed the operation said the Arab label was 80 cm below the present one”

(Dickie, 1976, p. 100)
2.3.3 Evidence from poetic inscription within Palace and Court of Lions

Within the Palace of the Lions, poetic inscriptions were engraved in pre-calculated locations communicating a precise intended meaning (Dickie, 1979). Normally they can be seen easily at eye level (Grabar, 1978). These iconographic inscription on architecture were not unique to Alhambra but were exceedingly rare before the 14th century and especially in the Mediterranean world (Grabar, 1978). The inscriptions aimed at three different purposes: the depiction of the water’s metaphors, and the affirmation of the integrity of the Palace, as well as its gardens (Rabbat, 1985). They were put in such a form as to imply that the building itself was speaking and explaining its purpose (Grabar, 1978; Hillenbrand, 1994). Many verses used first person as if the architecture spoke on its behalf and the building itself gave utterance (Ruggles, 2000). The poems were topical, referring not only directly to the building, but to the specific parts of the building in which they occurred (Grabar, 1978). For example, in the Hall of the Two Sisters, there is a significant qasida (verse) by court poet Ibn Zamrak inscribed in the stucco work above the dado placed at the eye level of people, if they were sitting on the floor or cushions. The important verses regarding the Hall’s composition and the existence of the two gardens are shown below:

1. I am the garden revealed in the new beauty every day. Observe my splendor and you will benefit in understanding my status

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9: And if they [The Gemini, mentioned earlier in the qasida in the context, of describing the Hall’s dome] were to appear in both its courtyards [The Palace] they would vie With one another in serving him [The King] as concubines pleasing him

12: In them [the two courtyards], there is a hall that achieved magnificence And by which the Palace has come to compete in beauty with the vault of heaven

19: We have not seen any palace higher in its appearance And clearer in its horizons, or ampler in its assembly halls

20: And we have not seen any garden, more pleasant in its freshness, more fragrant in its surroundings, or sweeter in its fruits.

This poem established the vision of the Hall of the Two Sister’s design composition and its relationship to the two gardens (Rabbat, 1985). Dickie explained verse 9 that “… the heavenly twins correspond to two courtyards, even though only one [Court of the Lions] is visible today.” (Dickie, 1992). He further explained that the poem literally describes the site line of the Palace which must have been calculated according to a predetermined angle of vision. For example in verse 19, it talked about the “clear horizons”; verse 20 “seeing a garden” from the Hall. As well, this same poem also described the use of plants in the two gardens which talked about fragrant flowers, fresh greenery, and sweet fruit of trees (Rabbat, 1985).

The strongest evidence of the existence of the garden within the Court of the Lions lies within the 2nd verse of the poem engraved on one of the twelve outer edges of the fountain. Only three verses are shown below (see Section 5.3.4.8 Fountain of the Lions for entire poem):
1:  *Blessed be He who gave the Imam Muhammad a mansion which in beauty exceeds all other mansions.*

2:  *and if not so; here is the garden containing wonders of art, the like of which God forbids should elsewhere be found.*

12:  *May the blessings of God for ever be with thee! May He make sure thy subjects obedient to thy rule, and grant thee victory over thy enemies!*

The first verse described the beauty of Muhammad V’s Palace which was much more beautiful than all other palaces. This verse also confirmed that the poem engraved on the edge of the fountain belonged to the Court of the Lions for Sultan Muhammad V. The second verse described the absolute beauty of the garden where God ensured that no other gardens could be more beautiful than this one. The final verse was a blessing from God to Mohammed V. These verses of the poems not only revealed the presence of the garden within the Court of the Lions, but described the extraordinary beauty and the quality of the garden.

2.4 RESEARCH ASSUMPTIONS

The following assumptions help to define the scope and the expectation of this research:

2.4.1 Garden atmosphere, “known” and “missing” elements

As mentioned in Section 2.1, an Islamic garden is “expected” to have a strong garden-architecture relationship. Hence the search for the garden atmosphere in this study is assumed to be the integration of all garden and
architecture elements by complementing and/or contrasting between or amongst the elements, an Islamic garden characteristic. Certain elements were “known” and already described by scholars and researchers. However the absence of the current spatial, aesthetic and spiritual aspects of the garden in the Court of the Lions raised the question: Are there elements missing that caused the incongruency between architecture and landscape? This question led to the investigation of the “missing” elements in this study. By combining the missing and already “known” elements, it was hoped that the garden atmosphere of the Court of the Lions in 1391 could be re-defined. All of the known elements collected from a primary literature review defined by previous researchers and scholars regarding the elements of the Court of the Lions were treated as “already known and defined” elements and assumed correct. They were the foundation to this research. These “known” elements were not further analyzed but were used “as is” elements that contributed to the overall garden atmosphere.

2.4.2 Presumed background knowledge from other fields

This research covered a very broad area during the search of literature. It drew on knowledge from other fields of study including Islamic garden ideology, the description of Paradise from the Holy Quran, microclimatic study of courtyards as well as scientific research on materials at microscopic level within the Court of the Lions and other locations in the Alhambra complex.

This research also depended heavily on the use of computer simulation models. The description of the use of technology in computer simulation will be addressed. The details of the actual 3D modeling process will not be covered in
this research. This process would be a research thesis in itself. An assumption is therefore made that the computer simulation models used in this study are appropriate for the task.

2.4.3 Physical Limit of Study

As mentioned earlier, Islamic garden design principles consider landscape as an extension of architecture. Hence it was necessary to include the physical architectural elements of columns, perforated screens, the covered walkway and the walls around the Court of the Lions in consideration of the garden. The physical limit of this study is governed by the boundary of the four massive walls surrounding the Courtyard (Figure 7).

Figure 7: Physical Limit of Study (white area)  (Source: Fernandez-Puertas, 1997a, p. 53; edited by the researcher)
2.5 RESEARCH GOAL AND OBJECTIVES

2.5.1 Research Goal

The goal of this research is to describe and explain the likely original garden atmosphere of the Court of the Lions in 1391 AD, the final year of Sultan Mohammad V’s second reign before he died.

2.5.2 Rationale of Research Goal

The research goal has the following rationale:

1. Research Rationale for the search for garden atmosphere

The idea to search for the garden atmosphere, rather than the original plant materials, came from a discussion in a conference proceeding. During the ICOMOS-IFLA Conference held in Spain, 1973, Mr. René Péchère raised the question whether it was really possible to re-create a garden that had vanished. In his opinion, it is not possible to know exactly what plant materials were used. Hence he suggested efforts should be spent on describing the garden atmosphere rather than presenting an array of plant lists (Riudor Carol, 1973).

2. Rationale for choosing the year 1391

It was mentioned earlier by Ruggles that the Palace of the Lions was built between 1370 and 1390. It would be logical to believe that the garden would have reached its maturity through twenty years of growth. Hence Sultan Mohammad V would have experienced the fully established and
the most original garden built for this Palace by the year 1391, the year when he died.

2.5.3 Research Objectives

- To search and to analyze evidence of any potentially missing landscape elements within the Court of the Lions using grounded theory and concept mapping technique

- To utilize computer 3D models and simulations as virtual test instruments to test the feasibilities of these missing elements

- To integrate the existing elements with missing elements within the Court of the Lions to re-define the possible garden atmosphere as it was in 1391

- To experience the garden atmosphere as it was in 1391 with photorealistic computer images and animations

2.6 RESEARCH RECOGNITION

This research has already been recognized at an international level. The findings from this research were accepted and presented to an international audience of researcher experts meeting at the 5th International Conference on Science and Technology in Archaeology and Conservation held in Baeza, Spain in July, 2007. The speech was well received. During a casual conversation with the organizer and director Dr. Talal Akasheh near the end of the conference, he commented that “…This landscape architecture research [on the Court of the Lions] is important. It sheds new lights and ideas in research particularly in the field of archeology.”
CHAPTER THREE: RESEARCH METHODOLOGY

3.1 RESEARCH EVOLUTION

This study evolved over a nine-month period. It grew from a simple desire to document a computer visualization process using content analysis data through historical illustrations and European visitors’ description, to an in-depth study that integrated recognized theory and research methods with the use of computer 3D models as a virtual test instruments and presentation tool. The decision to abandon the original research framework was due to the poor information recovered from the travellers’ description and illustrations. The surviving European visitors’ description of the Court of the Lions all took place after 1492. These descriptions of the Courtyard may be true to the European visitors’ own corresponding era. These ranged widely, variously including accounts of the Courtyard being fully covered in marble to containing six orange trees (Irwin, 2004). The inconsistency of these descriptions has become a topic for scholarly debate. While many researchers reported that some visitors saw oranges trees in the Courtyard, Enrique Nuere-Matauco argued that in the 14th and 15th century, the Courtyard had no vegetation but was paved in marble (Nuere-Matauco, 1986). Nuere-Matauco based this argument on the testimony of the German traveler Jeronimo Munzer, the first recorded visitor to the Alhambra, in 1494. Table 1 summaries in chronological order the visitors’ description of the Court of the Lions based on the information collected from a number of books and articles. The collected information includes visitors’ names, their profession, the year they visited the Court of the Lions, their description of the Courtyard as
well as the authors of the books and articles where the source came from. A few major events were also noted in terms of the year, description of the events, and their corresponding sources. The information presented in this table may not be exhaustive. However the table shows such inconsistency of the descriptions provided by visitors throughout history even though these descriptions were legitimate accounts of the Courtyard at different era. In the researcher’s opinion, the debate of the original Courtyard, whether it was paved or not, had little validity because the debate circled around the descriptions from European visitors of what they encountered from 1494 onwards. The earliest description was at least one hundred and two years after the completion of the Palace of the Lions in 1392 and was not considered as contemporary. It would not be sensible to use more than one hundred year old description to consider the originality of the Court of the Lions.

Table 1: European travelers who visited the Court of Lions – late 15th to 19th Century (compilation from different sources encountered)

<table>
<thead>
<tr>
<th>Year</th>
<th>Person</th>
<th>Profession</th>
<th>Event</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>1492</td>
<td>Mohammad XII</td>
<td>Last Nasrid Sultan</td>
<td>Surrender of Granada to Christian Army</td>
<td>Lopez and Andreu, 1999</td>
</tr>
<tr>
<td></td>
<td>Ferdinand and Isabella</td>
<td>Christian Conquerors</td>
<td>Moved into Alhambra. Found the palaces sadly rundown. Recruited Muslim craftsmen to do restoration work.</td>
<td>Irwin, 2004</td>
</tr>
<tr>
<td>1494</td>
<td>Hieronymus Munzer</td>
<td>German traveler</td>
<td>Marble covering of courtyard with fountain</td>
<td>Irwin, 2004; Nuere-Matauco, 1986</td>
</tr>
<tr>
<td></td>
<td>Antoine de Lalaing</td>
<td>French visitor</td>
<td>Saw 6 orange trees tall enough to stand underneath</td>
<td>Ruggles, 2000</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Saw 6 orange trees, but these are likely the survivors out of the original total of 8</td>
<td>Dickie, 1994</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Saw 6 orange trees</td>
<td>Prof. Tito-Rojo, 2006</td>
</tr>
<tr>
<td>1502</td>
<td>Philip le Beau</td>
<td>(unknown)</td>
<td>Saw 6 orange trees left</td>
<td>Villiers-Stuart, 1929</td>
</tr>
<tr>
<td>Year</td>
<td>Visitor/Architect</td>
<td>Event/Description</td>
<td>Notes</td>
<td></td>
</tr>
<tr>
<td>------</td>
<td>-------------------</td>
<td>-------------------</td>
<td>-------</td>
<td></td>
</tr>
<tr>
<td>1522</td>
<td>Ferdinand and Isabella</td>
<td>Earthquake damaged Court of Lions. Muslim craftsmen were used to repair the damage from earthquake.</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
<tr>
<td>1524-1526</td>
<td>Andres Navagero</td>
<td>Visited Alhambra and Generalife.</td>
<td>Ruggles, 2000</td>
<td></td>
</tr>
<tr>
<td>1590</td>
<td></td>
<td>Gunpowder explosion damaged Palace of Lions</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
<tr>
<td>1602</td>
<td>(name unknown)</td>
<td>Each quadrant contained 6 orange trees for total of 24</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
<tr>
<td>1775-1776</td>
<td>Henry Swinburne</td>
<td>Hard pavement with no plants</td>
<td>Nuere-Matauco, 1986</td>
<td></td>
</tr>
<tr>
<td>1828</td>
<td>Jose Contreras</td>
<td>Barely started work on restoration of Alhambra.</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
<tr>
<td>1829</td>
<td>Washington Irving</td>
<td>Saw flowerbeds, butterflies, and bees(^{14})</td>
<td>Irving, 1861</td>
<td></td>
</tr>
<tr>
<td>1831</td>
<td>Richard Ford</td>
<td>Arrived and stayed in Alhambra</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
<tr>
<td>1834</td>
<td>Owen Jones &amp; Jules Goury(^{15})</td>
<td>Detailed plan, section, elevation drawings and documentation of Alhambra</td>
<td>Goury, 1842</td>
<td></td>
</tr>
<tr>
<td>1837</td>
<td>Owen Jones</td>
<td>Revisited Alhambra and revised some of their work.</td>
<td>Goury, 1842</td>
<td></td>
</tr>
<tr>
<td>1840</td>
<td>Richard Ford</td>
<td>A la francesa style garden</td>
<td>Irwin, 2004</td>
<td></td>
</tr>
</tbody>
</table>

Furthermore the descriptions of the European visitors were questionable due to inaccuracy, lack of details or a mixture with imaginary descriptions. For example, Munzer mentioned in his book *Viaje por Espana y Portugal 1494-1495 (Travel to Spain and Portugal 1494-1495)*, that the white marble fountain was sitting on top of 13 white marble lions (Munzer, 1991) where in fact there were only 12 lions! Another example was regarding the locations of the famous orange trees. They were mentioned by many visitors but the exact locations of these trees were not described. The last example, but not least, was the famous book “The Alhambra” by Washington Irving. While the book contained beautiful and detailed descriptions of many parts of the Alhambra, Robert Irwin considered it as:

\[^{14}\] The garden description was Irving’s own imagination (see Irwin’s comments on next page).  
\[^{15}\] Goury died of Cholera in Granada in 1834
“… a literary scrapbook mixing visual evocations of the place with snatchers of folklore, romance, history and gossip…”

(Irwin, 2004, p. 139)

Irwin further commented that Irving used atmospheric cliché to:

“…conjure up a fantastic typography, compounded of phantoms, imprisoned princesses, buried treasures, moonlight, gypsies and banditti…”

(Irwin, 2004, p. 141)

The historical artists’ illustrations are similar to the European travellers’ descriptions in terms of their reliability. The exaggerated perspective and scale, with the unknown idea of the plants drawn in the pictures (Figure 8), gives the overall fictional sense of these illustrations. Figure 9 is a recent photograph of the Courtyard for scale comparison purposes.

Based on the questionable reliability discovered and the lack of detailed description of the garden, the information collected was not considered as reliable and accurate.

Figure 8: An artistic illustration of Court of the Lions by P. J. Girault de Prangey (1837)
(Source: Bermudez Lopez J. & Galera Andreu P, 1999, p. 113)
enough to satisfy the goal and objectives (Section 2.5) defined for this study. Pursuing the study with the information would simply mean the study would be building on “quick sand”. As a result all of the European visitors’ descriptions and the artistic illustrations did not advance beyond the data collection stage. A new research framework was needed to look for more concrete evidence.

3.2 THEORETICAL FRAMEWORK

With the sound lesson learned from the initial research, it became essential to search for evidence which could demonstrate facts rather than fiction. Hence all literature collected needed to be reliable (see Section 3.5 Measurement of Variables for details). A new research framework was established by collecting literature from different resources and languages throughout history. The literature included articles, books, personal contacts and additional drawings. By reviewing these sources, design elements within the Court of the Lions were identified and classified into architectural and landscape

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16 Note the Fountain of Lions was covered for restoration work during the researcher’s site visit.
elements. The latter were then further classified into “known” and “missing” elements. These possible and missing landscape elements were the focus of this study and were derived by utilizing grounded theory and concept mapping methods. Three different types of computer models, namely conceptual, illumination and photorealistic, were used throughout the landscape architectural research process as virtual instruments for testing the feasibilities of the missing

![Figure 10: Research Framework](image-url)
elements and for presenting the research findings. All elements, known and missing, were then integrated to portray the garden atmosphere in 1391. Figure 10 showed the generalized Research Framework.

3.3 RESEARCH METHODS

As a result of the lack of reliable documentary descriptions of the garden that date from Mohammad V’s time (1391), this research utilized the method of inductive reasoning to search for the missing landscape variables. This method had been used quite often by social scientists in the construction of a theory using the induction method by observing aspects of social life and then looking for patterns that may point to relatively universal principles (Babbie, 2004). This method was termed Grounded Theory by sociologists Barney Glaser and Anselm Strauss (Babbie, 2004)\(^\text{17}\). Babbie describes Grounded Theory as an inductive approach where researchers “…attempt to derive theories from an analysis of the patterns, themes, and common categories discovered in observational data” (Babbie, 2004, p. 291). Concept mapping was also employed, which is a technique to register ideas and find out the interrelationships between them in the form of pictures or maps (Trochim, 1989). Basically concept mapping is a type of structured conceptualization which refers to “any process which can be described as a sequence of concrete operationally-defined steps and which yields a conceptual representation” (Trochim, 1989)\(^\text{18}\). Concept mapping was


utilized in this study to map out, rationalize, and visualize the intricate relationships amongst elements in a graphic format for each variable under investigation. The diagramming of evidential relationships allows the variables to “speak for themselves”.

3.4 THE MISSING VARIABLES AND RESEARCH LOGIC

At the beginning of the research, it was hard to determine what elements were possibly missing, if any. It was through the review of a number of sources, with the utilization of grounded theory and concept mapping that a pattern started to emerge. This pattern led to the discovery of the first and the most important variable of this study --- “shade”. The other two aspects which were seen to structure this garden were “tree form and arrangements”, and “shrub types and arrangements” (see Chapter 6: Analysis and Findings for details). These landscape elements were not independent variables but rather dependent and

![Figure 11: The Investigation Process for the Missing Variables](image)

Figure 11: The Investigation Process for the Missing Variables
closely related. For example, in order to determine what types of shrub were used, it was necessary to determine whether trees were present or absent at the time. Once it was determined likely that trees were present, it was then possible to know the overall brightness of the Courtyard and the shade density generated from different trees, and then decide upon the corresponding shrubs which would flourish or not on the basis of these shade densities. Figure 11 showed the generalized sequence of landscape related investigations arranged in a logical order starting from the widest perspective of physical and cultural contexts proceeding to specifics of the garden, attempting to define or re-define the likely Nasrid period configuration of the Court of the Lions.

3.5 MEASUREMENT OF VARIABLES

3.5.1 Reliability of this research in general

Reliability is a measure of a particular technique which would yield the same results each time when applied repeatedly to the same object (Babbie, 2004). In order to establish reliability for this research, all literature collected maintained total transparency so that future researchers could obtain the same conclusions. As well, the procedures for deriving the missing landscape variables were based on logical development with the aid of grounded theory, concept mapping methods and 3D computer simulation models. Future researchers could follow the procedures to re-establish the same or similar study results.
3.5.2 Reliability of the Shade variable

The study of the shade variable depended upon the collection of site and supporting evidence. Site evidence included scientific research carried out within the Court of the Lions and the Alhambra complex. The supporting evidence included microclimate studies of courtyards in hot countries, metaphysical descriptions of shade in Paradise from the *Holy Quran* and *Hadith*\(^\text{19}\), as well as Islamic Garden design element and concept of shade. Although all collected information were biased towards scientific and spiritual evidences, these sources represented a diverse range of information from a microscopic scale study of marble to the physical scale of the Courtyard and the metaphysical scale of the description of Paradise in the *Holy Quran*. The utilization of such diversified data, collected from different professional disciplines helped to ensure the reliability of the end result which focused to the question of shade (see Figure 12). As well, both the scientific and spiritual sources provided repeatable results. Remarkably, these two sources had a strong relationship with one another. Since Islamic gardens

\(^{19}\) *Hadith* is the teachings of Prophet Mohammad (p.b.u.h.) The letters p.b.u.h. stands for "peace be upon him". This is a special salutation used by Muslims whenever Prophet Mohammad’s name is mentioned. Similar ones are used for Prophet Jesus, Moses and other Prophets and messengers.
are the terrestrial image, reflection and anticipation of Paradise (Van Zuylen, 1999), it was expected that the scientific evidence found in the Courtyard would have strong meaningful relationships with the spiritual elements described in the Holy Quran. The latter has given a context to the modeling of the configurations proposed by this study.

3.5.3 Reliability of the Trees and Shrubs variables

The study of the other two variables namely “tree form and arrangements” and “shrub types and arrangements” were conducted using computer simulation models. Computer models have been recognized for their accuracy and repeatability. Provided that these variable studies were simulated according to the described procedure in this research, anyone who repeated these experiments with the same, or similar, software should obtain the same result. 3D modeling procedure will be covered in Section 4.3 The Use of 3D Concept Model and Section 4.4 The Use of Computer Illumination Model while the experiment procedures for trees and shrubs will be described in Sections 6.2.4 and 6.3.3 respectively.
The desire of human beings to describe their spatial experience and memory of place can be traced throughout the evolution of human civilization: the cave painting of ancient times (Tannenbaum, 2000); the invention of mathematical perspective techniques in the 15th Century (Zube et al., 1987); the introduction of motion on large screen cinema (IJsselsteijn et al., 2001); as well as the development of software for digital image editing, CAD and 3D modeling (Zube et al., 1987). It was the successive development of these technologies which provided better tools to describe the spatial experience of places. The sensation of spatial experience created by using 3D models also gives an opportunity to (re)experience the spirit of a place in the future or the past.

Within the field of landscape architecture, the effort for creating spatial experience can be traced back to Humphry Repton’s work in 18th Century England. He used perspective illustrations and cut-and-paste techniques to demonstrate his proposed design to his clients in his famous Red Books (Lange, 2001). Since the 1980s landscape architects made use of GIS software to perform a number of design and visual communication as well as data computation tasks. These tasks include proposed alternative land cover configurations; realistic renderings of possible landscape scenarios and review outcomes on a variety of environmental, economic and social scales (Stock & Bishop, 2002). Researchers in the recent years such as Eric Lange, Stephen Sheppard and others have made use of the advanced software capabilities to develop large scale photorealistic visualization for planning applications (Lange,
Computer images and pre-rendered computer animations have been used regularly to convey these proposed design changes.

This study made use of the computer visualization technology for the past. It relied heavily on the use of three types of computer modeling, namely Concept, Illumination and Photorealistic Models (see Section 4.3, 4.4 and 4.5 respectively). These simulations were invaluable virtual tools for this study and were transparently used throughout the research process. These virtual test instruments helped immeasurably with the research findings and were essential to the outcome.

4.1 COMPUTER MODELS REFERENCES

Architectural drawings of the Court of the Lions were extremely rare. Exhaustive search included the survey of books, liaising with rare book librarians in three Toronto libraries, using the University of Guelph online search portals, as well as exploration of books, architectural printed materials and liaising with the staff at the Alhambra book store during the researcher’s 2007 site visit. The following references were the only two architectural sources found. They were used for 3d modeling:

- Column details (Figure 13) and plan drawing (Figure 14) from:

- Elevation drawings (Figure 15 and Figure 16) from:
Figure 13: Column details of Court of the Lions  
(Source: Fernandez-Puertas, 1997a, p. 81)

Figure 14: Plan Drawing of Court of the Lions  
(Source: Fernandez-Puertas A., 1997a, p. 53)

Figure 15: Elevation (North) of Court of the Lions  
Source: Goury J. and Jones O, 1842, Plate XIV
Figure 16: Elevation (East) of Court of the Lions
Source: Goury J. and Jones O., 1842, Plate XV

4.2 SOFTWARE USED

The following software was used for this study:

<table>
<thead>
<tr>
<th>Software</th>
<th>Used for</th>
</tr>
</thead>
<tbody>
<tr>
<td>SketchUp 5 and SketchUp 6 Pro</td>
<td>Concept model and interactive exploration</td>
</tr>
<tr>
<td>Lightscape 3.2</td>
<td>Illumination studies of elements</td>
</tr>
<tr>
<td>VUE 6 Infinite</td>
<td>Photorealistic images and animations</td>
</tr>
<tr>
<td>Photoshop</td>
<td>Texture editing and colour correction</td>
</tr>
</tbody>
</table>
4.3 THE USE OF 3D CONCEPT MODEL

Figure 17: 3D Concept Model (Aerial Perspective View in wireframe mode)

This concept model (Figure 17) was created originally in SketchUp 5 and eventually migrated to SketchUp 6 Pro as it became available. The model created was based on four architectural drawings (Section 4.1) with the use of a number of photographs from researcher's site visits on July 5, 2007 (see Section 5.7 Site Visit: A Day in the Court of the Lions). The model could not be built as a 100% true replica of the real world counterpart due to the lack of numeric dimensions. However, despite the limited information, the researcher managed to create the computer model to resemble the correct appearance and proportion of the Court of the Lions. It was done by setting up the plan and section drawings in the virtual space within SketchUp (Figure 18). The architectural footprint was then directly traced from the virtual plan drawing. The outlines of all architectural
elements were then traced from the virtual elevation drawings. The elements were then positioned in the virtual 3D space by referencing their locations based on their corresponding indications from the virtual plan and elevation drawings.
High resolution site reference photos helped to verify the correct 3D form of the architectural details. Figure 19 showed the work-in-progress construction of the 3D model using the above procedure.

**Purpose:**

The purpose of building the concept model of the Court of the Lions with simplified geometry was to allow real time interaction for placement and movement of objects. Not only could the computer user get a sense of the space, but more importantly the interactivity allowed him/her to simulate and develop scenarios around the placement of objects based on the spontaneous real time action-and-reaction. For example the action-and-reaction interaction helped to simulate tree sizes, arrangements as well as “seeing” the corresponding shadow of objects generated in real-time by the computer.

**Usage:**

- Analysis of tree form and arrangements (see Section 6.2.4)
- Analysis of shrub types and arrangements (see Section 6.3.3)

**General procedure:**

The plan drawing and column details were digitally scanned at 600 dpi resolution using a typical desktop computer scanner. The Goury J. and Jones O. (1842) elevation drawings were digitally scanned at 600 dpi resolution at Thomas Fisher Rare Book Library in Toronto because the book belonged to their rare book collection which needed to be handled by their librarian. The plan drawing was directly imported into SketchUp as a base image and resized to 1:1 scale. All known elements such as walls, columns, Chahar Bagh, fountains, roofs,
perforated screens, pavilions, were traced and built three-dimensionally by referencing against the plan and the two elevation drawings. A number of photographs from different books and site photos from the researcher were also used for quick visual references during the construction of the model.

**Problem encountered:**

The biggest problem during the construction of the computer model was encountered when following the metric measurements shown in the plan and elevation drawing of the architectural column. As the modeling process progressed it became impossible to build any details of elements which were expected to obey the Islamic architecture building principles on the proportion system. The measurements could not be subdivided into any whole numbers. Furthermore the metric scale was not invented at the time of construction some eight hundred years ago. Professor Fernandez-Puertas argued that the Palace was built using a proportional system with the fixed Hispano Muslim units called *codo* which was based on Roman *pedes* or *foot*. The *codo* was the measuring unit used in the 11th century Great Mosque of Cordoba and it has been shown to have been widely used in Muslim architecture throughout Spain (Irwin, 2004). By converting the metric units of measurement “back” to the older imperial units, all elements started to reflect the great proportional system once again. For example, instead of using the metric scale bar on the drawing for the measurement of column height to be 274cm, the “real” height should be expressed as 9 feet (274.23cm) as a whole number using the imperial scale.
4.4 THE USE OF COMPUTER ILLUMINATION MODEL

Figure 20: Illumination Model with no trees (Work-In-Progress model)

The illumination model (Figure 20) was created using the lighting analysis functionality of the software known as Lightscape. It was released in early 1990s which revolutionized the quality of realism in computer imagery by the introduction of Global Illumination calculation. In essence, Global Illumination is a rendering algorithm that takes into account the ways in which light is reflected between the surfaces in the model. The process takes extremely long computation time but the rendered image is a representation of an accurately lit virtual environment which obeys the law of physical property of light in reality. While the software is capable to generate stunning photorealistic images for architectural objects, from the researcher’s experience using the software, any organic 3D objects such as trees and shrubs failed to reach the same
photorealism level. Furthermore by today’s standard, the software lacks many functionalities when compared to other photorealistic capable software. Hence only the lighting analysis functionality of the software\(^{20}\) was used.

**Purpose:**

The purpose of using the illumination model was to study and compare the amount of light energy received on all surfaces of the model when trees were absent or present during the testing of the tree variable.

**Usage:**

- To analyze the amount of light energy received on all surfaces when trees were absent (see Step 4 in Section 6.2.4 for details)

- To analyze the amount of light energy received on all surfaces when trees were present (see Step 4 in Section 6.2.4 for details)

**General procedure:**

The concept model was directly imported from SketchUp 6 Pro into Lightscape 3.2. Geographic coordinate of Granada, where the date and time were inputted into the software for lighting simulation. This will be explained in detail in Section 6.2.1. After the completion of the Global Illumination calculation, the lighting analysis functionality was then used for displaying the calculation result. This process needed to be repeated for simulating the Courtyard with trees and without trees. These light analysis images helped to “see” the light energy received on different surfaces under the different lighting conditions with and without trees.

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\(^{20}\) The researcher recalled that Lightscape was acquired by Discreet around 2002. The state of the art Global Illumination technology became a standard function for 3D Studio MAX 5. Unfortunately the equally advanced lighting analysis functionality was discarded permanently, probably due to lack of popularity.
4.5 THE USE OF PHOTOREALISTIC COMPUTER MODEL

VUE 6 Infinite was the software used for its capability for photorealistic imagery and for the creation of plant elements. The software is known for naturalistic plants and landscape creation and has been used by major production studios for film making when a photorealistic landscape environment is required.

**Purpose:**

The purpose of using VUE 6 Infinite was to make use of its sophisticated software functionality to generate a high level of photorealistic imagery (Figure 21) to bring out the architectural and landscape details of the Court of the Lions in

**Figure 21:** Photorealistic Computer Model (Work-In-Progress model)
order to re-experience the garden atmosphere as it was in 1391 using computer images and animations.

**Usage:**

- To create photorealistic computer images and animations re-enacting the garden atmosphere in 1391 as a presentation tool (see *Section 7.3*).

**General procedure:**

The detailed computer model came from successive refinement from the original Concept Model built in SketchUp 6 Pro (see *Section 4.3*). Some of the simplified elements for the concept model were remodeled in SketchUp 6 Pro to match closely with the architectural details in the real world. Textures were extracted from the researcher’s high resolution site photographs taken during his trip to Spain for the conference. They were touched up in Photoshop to eliminate any imperfections and to provide for colour correction. The original colours on the architecture were then digitally painted onto these corrected textures with references to an artistic illustration (see *Section 5.3.4.3*) from *The Official Guide - The Alhambra and Generalife* published by the Alhambra Authority, Patronato de la Alhambra y Generalife in 1999. These coloured textures helped to increase the photorealism of the refined model and were applied to different architectural elements in SketchUp 6 Pro. The finished detailed model with texture was then imported into VUE 6 Infinite for the addition of plant materials. Similar to Lightscape, the model in VUE 6 Infinite also needed to go through a time consuming Global Illumination calculation process for the creation of photorealistic images and animations.
4.6 CONSIDERATIONS FOR GLOBAL ILLUMINATION IMAGERY

Computer rendering is a complex process of registering the 3D virtual objects onto a 2D image. The idea is similar to taking a picture of a room in the real world. The room is a 3D space while the picture is a 2D image of the room at a specific location and time. The realism of computer images come from the Global Illumination calculation of how the light is received and reflected from all surfaces within the computer model. Objects’ colours, reflections, refractions and transparencies, as well as light intensity and so on, all needed to be calculated for all surfaces with their interaction with each other. A simple analogy would be a computer model with a white wall which picks up traces of red colour when a red ball is placed next to it. The calculation time for Global Illumination of this simple model would only take a few minutes at television NTSC resolution (720 x 480 pixels). However on a complex model such as the Court of the Lions, it would take approximately 2 hours to generate an image at the same resolution. In the case of an animation, it requires 30 images to be displayed sequentially per second, known as frames per second or fps. In order to generate one second of animation at NTSC resolution, it would require 60 hours or 2.5 days. Hence for the generation of a 30 second computer animation, it would take 75 days for rendering time! To make the situation worse, if the design is changed for any reason, the 30 second animation needs to be completely re-rendered for another 75 days! This intensive rendering process can be speeded up by rendering over a network of computers simultaneously. For example, for a network of 5 computers, the rendering time can be cut down to slightly more than 15 days. In
view of the extremely long computer rendering time using Global Illumination, Ambient Occlusion calculation was used instead. Ambient Occlusion is an approximation calculation method of Global Illumination, but still maintains convincing photorealistic quality. However the rendering time for an image is much shorter, only approximately 45 minutes instead of 2 hours using Global Illumination.
CHAPTER FIVE: LITERATURE REVIEW

The literature review centered on the collection of information related to the Court of the Lions. It can be viewed as a literary collection of “evidence” which encompassed literature from other fields of research area including background history of the Palace of the Lions, the *Holy Quran* and *Hadith*, Islamic garden design concepts, as well as microclimate research of courtyards in hot-dry areas and scientific studies at a microscopic level carried out within the Court of the Lions. Knowing that all of these study topics are enormous research areas by themselves, only information that are related to the Court of the Lions was collected.

5.1 A QUICK SUMMARY OF ISLAMIC GARDEN DESIGN CONCEPT

Islamic gardens were built by Arabs, Persians, Mughuls, and Turks, spanning from India to Spain (Nassar, 2002). The gardens were superimposed on indigenous cultures (ibid) pre-dating the three great monotheistic religions, Judaism, Christianity and Islam, by centuries (Clark, 2003). Its design had been enriched with variable experience and traditions inherited from old civilizations of Egypt, Greece, Rome and Byzantium (Abdine, 1986).

The Islamic gardens display a fundamental unity over different regions and times due to the oneness of the source of inspiration: the Islamic faith (Nassar, 2002). It was the Paradise imagery from the *Holy Quran* which provided the link among Islamic gardens (Nassar, 2002). The purpose of both the Quranic description and the physical garden can be considered as the same:
“...to prepare the mind of the believer, to give a portent of foretaste of the bliss which is experienced in those transcendent psychic states which transform the mind of the dweller of this world into the mind of one who dwells in a heavenly Paradise. A portent of a mental transformation”

(Blakstad, 1986, p. 22)

In essence, Islamic gardens can be summarized as a terrestrial image, a reflection and anticipation of the Paradise (Van Zuylen, 1999). To a Muslim, a garden is the symbol of paradise on earth (Brookes, 1987) and should therefore “exude beauty and peace” (Ali, 1999, p. 103).

The elements of Islamic garden design are driven from descriptive verses of Paradise from the *Holy Quran* and *Hadith* (Nassar, 2002). These two sources provided the characteristic, form and design vocabulary of the Islamic garden namely the quadripartite design, water features, shade, vegetation, pavilions, walls and gates (ibid). Whatever type and wherever the Islamic garden may be, its principal elements are water and shade (Brookes, 1987; Clark, 2004) and their descriptions appear in more than one hundred and twenty references in the *Holy Quran* (Clark, 2003). Trees provide the necessary shade and “are not clipped so much by letting them remain in their natural beauty” (Jay, 1931, p. 105). Great thought is used in making the garden in a climate where “heat from the sun is the sought-after and cherished element, while water and shade are plentiful and taken for granted” (Clark, 2004, p. 19). These key elements of “flowing water and shade, together with the exuberant foliage, powerfully convey ideas of both spiritual and physical refreshment” (Clark, 2003, p. 85). The ultimate goal of
these earthly ‘gardens of paradise’ is to provide “beautiful and harmonious surroundings, a retreat from the world, where the soul can let go of distracting thoughts and be at peace” (Clark, 2004, p. 32).

5.2 ISLAMIC GARDEN IN ANDALUCIA

5.2.1 History of Islamic Garden in Andalucia

The Islamic conquest of Spain in 711 signified the blossoming of the brilliant culture of the Ummayads at Cordoba. The Arabs brought with them architectural forms and elements of garden design together with the principles of oriental art (Prieto-Moreno, 1973a). After the domination of the Abbasids in Damascus, the grandson of the Umayyad Dynasty left Syria for Cordoba in Spain. He transferred many ideas of garden design from Damascus to Cordoba and Al Zahra (Abdine, 1986) and recreated the beauty of the gardens from distant land. These ideas included mingling trees and shrubs with water courses, fountains and cascades where people could enter a world where streams murmured into pools of sparkling water (Scurr, 1991) where people could be free to relax in a garden. Despite being exposed to intense heat, the garden gratifies their eyes, ears and sense of well-being (ibid).

Andalucia was considered to be an earthly paradise (Taylor & Cooper, 2000). As desert dwellers, the smallest drop of water or the slightest indication of nature’s greenness was considered precious and sacred (Clark, 2004). To them the oasis was a garden. So an extension of this oasis with more water and more trees, as described in the Holy Quran, was considered miraculous and heaven-
sent (Clark, 2004). With this concept of oasis in mind, when the Arab Muslims conquered Persia, Syria and Spain, all of these countries possessed abundance of water when compared to Arabia. Hence they believed they had found their earthly paradise (Clark, 2004).

The creation of gardens was made possible due to the Arab’s contribution to the re-establishment of the disintegrated irrigation system left behind by the Roman Empire in the 5th century (de Araujo, 1973). The Arab’s effort created a much more sophisticated network of irrigation system and laid the foundation for the transportation of water to every corner within Andalucia. It can be said that the original Roman tradition of using water was enriched by Hispano-Arab sensibility and decoration style (ibid). Ultimately this made the water available for sustaining the growth of gardens and for other purposes such as the irrigation of crops.

“… without their [Arab] ingenuity in designing channels that follows the natural terraces of the hillsides, the profusion of fountains and jets at the Generalife and the Alhambra, would have never been possible”

(Casa Valdes, 1987, p. 35)²¹

The water effect achieved by manipulation of flow of water was certainly intended and designed by the Palace builders (Abdine, 1986). The water was brought from the River Darro at the foot of Sabika Hill to the site by means of a complicated canalization system and aqueducts (Grabar, 1978; Rabbat, 1985) known as the Royal Canal (Acequia Real) to the Generalife and then to the

Alhambra (Bermudez Pareja, 1973; Rabbat, 1985). The water was then further divided up by a complex system of canals, small channels and underground pipes (Bermudez Pareja, 1973). Compensating basins and reservoirs enabled large supplies of water to be stored and the rate of flow to be regulated (Bermudez Pareja, 1973). This original water system was replaced by modern piping “without effort being made to record the old” in the 20th century (Dickie, 1979, p. 64).

Arabs introduced the art of water gardening to Granada with supreme luxury to devise refreshing private retreats in the midst of baking heat (Scurr, 1991). They seemed to have exercised all their gardening knowledge and art in Granada, and their influence lingered on in Spain through the centuries (Casa Valdes, 1987). The garden of the Nasrid Dynasty in Granada (1238-1492 AD) used the whole range of elements (Prieto-Moreno, 1973a) which echoed the description of Paradise in the Holy Quran (Taylor & Cooper, 2000) mentioned in Section 5.1 A Quick Summary of Islamic Garden Design Concept. These “contrived to symbolize a whole culture and its attitude towards sensuous pleasures” (Prieto-Moreno, 1973a, p. 174). Their great love and knowledge of plants, flowers and trees was:

“… a love born of the deep belief that the beauty of nature was a reflection of a transcendent truth of God; these plants and flowers are the shadow of their heavenly archetypes, their beauty a radiation of God’s glory on earth”

(Clark, 2003, p. 86)22,23,24

23 Clark cited in Translation of Holy Quran Chapter 56:10 by Yusuf Ali
24 Clark cited in Holy Bible Genesis, II:10
Although during the research period of this study no records were found as regards to the number of gardens in Granada, we can get the sense of the popularity of water gardens from Seville. It has been estimated that there were 50,000 villas with water gardens in the Seville district alone during the Arabs' dominion in Spain (Scurr, 1991).

The promotion of coolness, shade and seclusion in Spain (Lehrman, 1980) was the primary objectives of Arab and Muslim gardeners for creating a peaceful contrast with the heat and feverish atmosphere of the outside world (Scurr, 1991). They were masters at providing relief from inhospitable climates (Scurr, 1991) and were unsurpassed in their treatment of water (Jay, 1931). They understood that in order to create comfort, both plants and humans must be cooled and shaded (Stapley & Byne, 1923). Therefore, instead of every effort being made to catch and hold the sun’s rays; to avoid them was most important (ibid). Trees, such as cypress, palm or pine, were often placed in the center of flower bed to create shade (Lehrman, 1980).

5.2.2 Characteristics of Islamic garden in Andalucia

Islamic garden details are “differently conceived according to the cultural content” (Dickie, 1986, p. 78), but all according to the universal layout of the Chahar Bagh. The Andalucian garden was considered a regional version of the Islamic garden (ibid). Typically they had an urban setting, with manicured plants and were generally small in size (Lehrman, 1980). Even large spaces were divided into smaller and linked enclosures (ibid) in the form of courtyards. The gardens of Alhambra are good examples where the gardens were not only as a
court yard space but “intervening between palatial elements conceived as units within an overall scheme” (Dickie, 1986, p. 78). Prieto-Moreno explained:

“… the skilful use of nature in planning of the buildings, getting the fullest possible advantage from the position, and letting vegetation penetrate to the most intimate corners, thus carrying the project [Alhambra] to the very extreme of naturalism.”

(Prieto-Moreno, 1962, p. 12)

Hence the Courtyard space became an integral part of architecture (Harvey, 1974) and was considered as outdoor extension of the building (Irwin, 2004). The building was built to frame the views of the luxuriant gardens (ibid). In other words, the gardens took precedence over the buildings (ibid).

James Dickie mentioned that out of the period literary sources about gardens in Andalucia, only two have been found extant (Dickie, 1976). This was probably due to the scarcity of documents prior to 1492, mentioned in Section 2.2 Research Difficulties and Limitations. One of the sources was from a Cordovan text of the 11th century and the other an Almerian manuscript of the 14th century. Dickie commented that although these two descriptions of gardens were separated by three centuries, they demonstrated that the use of garden elements underwent no significant changes within the time interval (Dickie, 1976).

Besides the possession of the typical elements of Islamic gardens, and being small and enclosed as mentioned earlier, the Islamic gardens in Andalucia also contained the following unique “regional” Islamic garden characteristics
namely: sunken planting beds, the use of tiles and the elaborate use of plant materials.

5.2.2.1 Sunken planting beds

The planting beds were sunken into the ground. They add geometric character to the enclosure (Dickie, 1976). As well they make the shrubs, planted in these sunken planting beds, visually into a “floral carpet” (Dickie, 1976). Most importantly the sunken planting beds were for irrigation of plants in hot climate (Clark, 2004) by retaining the moisture of the soil after watering using the shade of plant materials grown within for an extended period of time. Examples of sunken gardens in Andalucia include: Patio del Alcazar Viejo in Seville built in the 11th century (de Araujo, 1973); Madinat al-Zahra outside Cordoba (Dickie, 1976) (Figure 22); Court of the Myrtles within Alhambra (Casa Valdes, 1987); Patio de la Acequia within Generalife (Van Zuylen, 1999) (Figure 23); a garden in Qasr al-Mubarak Palace within Alcazar in Seville built in 12th century (Dickie, 1976) (Figure 24); another garden within the same Alcazar in Seville built in 11th century (Dickie, 1976) (Figure 25).

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25 Sunken plant beds with irrigation by narrow channels fed by the pools. Outlet holes were found on both sides of each channel of which one has been discovered intact at a corner of a flower bed, to permit irrigation of the beds (Dickie, 1976).
26 Planting beds were one yard deep under the pavement creating the effect of a dark green carpet etching of the rectangular pool (Van Zuylen, 1999).
27 The original planting beds were a half yard lower along the Patio de la Acequia (Van Zuylen, 1999) with some deeper pits made for the roots of shrubs and trees (Ruggles, 2000). Generalife was built in early 14th century (de Araujo, 1973; Ruggles, 2000). This description is almost the same time period as Palace of the Lions.
28 Sunken flower beds about six feet deep (Dickie, 1976)
29 Planting bed fifteen feet below surrounding level (Dickie, 1976)
Figure 22: Madinat Al-Zahra (left); outlet holes of a sunken plant bed (right)
(Source: Dickie, 1976, page XVI, Fig. 2 & 3)

Figure 23: Section of the original level of plant bed in Patio de la Acequia
(Source: Schofield, 1982, p. viii; edited by the researcher)
Note: Faded out objects represents the current level of plant bed

Figure 24: Garden in patio at Qasr al-Mubarak, Seville
(Source: Dickie, 1976, page XVII, Fig 4)

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30 Schofield cited in Prieto-Moreno, *Los Jardines de Granada*, p. 93
Figure 25: Another sunken garden in the same Alcazar, Seville (in 11th century)  
(Source: Dickie, 1976, page XVIII, Fig 7)

5.2.2.2 The use of coloured tiles

The coloured tiles add colours to the gardens. Often the whole colour scheme of the garden depends on the colour of the tiles (Jay, 1931). Cool colours such as blue, yellow, green and black were used while red was seldom used (ibid). Very often channels were lined with blue tiles set at angles so that when water flowed over them, the water would break up causing ripples on the surface to catch the sparkling reflection of sunlight (Clark, 2003). These blue
ceramic tiles were also used in pools to increase their apparent depth as well as to soothe the body and refresh the spirit (Scurr, 1991).

5.2.2.3 Elaborate use of plant materials

The climate in Spain allows the most unlikely combinations of plants from temperate and tropic zones (Harvey, 1974). Exotic plants were deliberately acquired from the East notably India and China (Bolens-Halimi, 1992; Jay, 1931) and transplanted in Andalucian soil as early as 8th century (Ruggles, 2000). By the 10th century, the royal gardens at Cordoba seem to have become botanical gardens, with fields for experimentation with seeds, cuttings and roots brought in from the outermost reaches of the world. Other royal gardens, in Andalucia and elsewhere, also became the sites of serious scientific activity as well as places of amusement (Gardens of Islam, 2002)31. Only many centuries later did Europe possess similar botanical gardens (ibid). Comparison with the almost exactly contemporary English book Feate of Gardening provides convincing proof of the relatively advanced state of the art in Andalucian gardening by the Muslims when compared to that of north-west European Christendom (Harvey, 1992)32. The garden development gap between Andalucia and Europe could be explained by the historic fact that while Islamic sciences and horticulture flourished, Europe was just emerging from the Dark Ages (Clark, 2004).

Other than the functional reasons such as creating shade, plant materials played an important role aesthetically and were selected carefully to fit the

growing conditions in confined spaces of courtyards. The common “rule” or idea for plant selection was:

“No matter how much the trees and plants grew, they [canopy] never interfered with the architecture around them”

(Ali, 1999, p. 105)

Plants cannot visually block the facades of the buildings which were normally decorated in meticulous details with vibrant colours for visual appreciation during the Nasrid period. Please see Section 5.3.4.3 for details regarding colours on architecture.

Another common idea was that, since gardens were considered as extension of buildings, the trees were normally planted and aligned with the columns of the building to emphasize this “extension” visual effect. A good example would be the Great Mosque in Cordoba where the trees in the courtyard were placed in a grid formation and aligned with the position of the interior columns of the Mosque (Figure 26). The alignment effect also gives a sense of Order which is paramount in Islamic garden (Clark, 2004). In Islam, Order is “the source of peace” which also reflects the law of the Cosmos (ibid, p. 39).

During the researcher’s site visit to the Grand Mosque, he felt that the orange trees currently grown within the courtyard were not appropriate to the vast scale of the courtyard based on his landscape architectural design experience. Currently it was not possible to see a person on the other side of the courtyard without slightly lowering the body of the observer due to the visual interference of the canopy of the orange trees. The search for a more appropriate plant material is beyond the scope of this research.
5.3 PALACE AND COURT OF LIONS AND THEIR RELATIONSHIPS

5.3.1 Background information of Palace of the Lions

Sultan Mohammad V returned from exile from Fez, Morocco, and recovered the throne on 16th March 1362 (Fernandez-Puertas, 1997b). In December of the same year, he held a big party on the future site of the Court of the Lions and invited Kings, Queens, merchants and people from different social classes (Garcia-Gomez, 1988; Irwin, 2004). During the second part of the divided reign of Sultan Mohammad V (1362-1391), he undertook the construction of Palace of the Lions around the beginning of 1370 (Fernandez-Puertas, 1997b). The location of the Palace replaced an older garden from Yusuf I and was built
on artificially levelled land (Ruggles, 2000). The Palace of the Lions occupied two terraces, the upper and lower, with the Hall of the Two Sisters, projecting into the lower terrace in the now vanished garden (Dickie, 1992). The Palace of the Lions represents the highest achievement, specifically in the sensitive use of water, and its respect of the topography and environment of the City of Granada (Rabbat, 1985).

Historic materials before 1492 had been hard to find (Ruiz Souza, 2001). Besides the physical remains of the building, there was not much known about the Palace itself. Robert Irwin warned visitors that:

“…those who visit the Alhambra today need to be aware that what they see is only a small part of what was standing in 1492 [before the Reconquista].”

(Irwin, 2004)

Even the name of the Palace was not known for certain by the mediaeval Arabs who used to inhabit it (Irwin, 2004). The Palace and the Court of the Lions are modern names given to the Palace and the Courtyard because of the 12 lions located in the middle of the Courtyard (Ali, 1999; Irwin, 2004). Recent research has described it as “The Palace of the Riyad” or “of the Garden”, since there was a garden there before the present buildings (Bermudez Lopez & Galera Andreu, 1999). As well, Fernandez-Puertas deduced the same name from Ibn Zamrak, the Court Poet to Mohammad V, who described the Palace as the Palacio del

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34 Ruggles cited in Pavon Maldonado, Estudio, I, 76
“Riyad” (Garden Palace), though it has been known in Christian times as the Palacio de los Leones (Fernandez-Puertas, 1997b).

It has been equally difficult to determine the Palace’s precise function (Grabar, 1978; Ruggles, 2000). Very little has been brought out to indicate precisely how these rooms were used (Grabar, 1978). What was far worse was the fact that there had been no adequate archaeological parallels or literary references which could allow people to imagine the life in these palace complexes or to explain them through better-documented examples (ibid). Scholars have speculated at length about the functions of the various rooms in the Alhambra, but Professor Fairchild Ruggles explained that:

“...there is no documentary information about who was entertained in which area of the palace, or where the sultan slept and ate, or where his family resided, these speculations are only inferences from the organization and chronology of the architecture and the poems displayed on its walls”

(Ruggles, 1997, p. 188)

5.3.2 Functionality suggestions of Court of the Lions

Similar to the undetermined function of the Palace, the use of space for the Court of the Lions is not known. The prevailing, and most logical, idea is that the Court of the Lions was “built within the state palace for the relaxation of the ruler in an informal surrounding” (Dickie, 1979, p. 56). It was the place where the Sultan could have a few quiet moments to “escape from protocol and the formal arrangement of space which protocol entails” (ibid). This relaxation idea seemed
to run parallel with the purpose of Islamic garden where it is solely used for relaxation “through the five senses” (Clark, 2004, p. 57) and as a reminder to the believers of the presence of God. However Juan Ruiz Souza argued that the Court of the Lions was not a palace but a madrassa, an Islamic religious school. He suggested that the Court of the Lions would have lodged scholars who studied *Quran, Hadith* (the teachings of Prophet Mohammad, p.b.u.h.), theology and religious laws and perhaps also have served as the forum for scholarly debates conducted in front of the Sultan. His idea was based on Ibn Battuta who was in Fez in 1349 and described that Sultan Mohammad V was holding scholarly assemblies everyday after the dawn prayer in the main mosque (Irwin, 2004). Ruiz Souza further believed that that “Mohammad V’s tomb may have been located within the Hall of Abencerrages” (Irwin, 2004, p. 97) because pious Muslims who established madrassas often buried in the same place in the hope that this virtuous act would ensure their soul’s salvation (Irwin, 2004).

From the researcher’s point of view, Ruiz Souza’s idea may not be appropriate within the setting of the Court of the Lions. Firstly, if the Sultan’s tomb were located in the Hall of Abencerrages, one would expect to see a rectangular box shaped tomb structure extruded from the ground signifying that this would be his resting place in this world. It would be decorated and engraved with verses from the *Quran* along the edges of the tomb structure with specific script like, “May you rest in peace here and may Allah blesses you and grant you to the highest level of Paradise.” Furthermore the tomb structure would have the most beautiful decorations on all of its surfaces to glorify his contribution to the
society and as a role model due to his noble Muslim character (see Section 8.2). There is no such structure present in the Hall of Abencerrages other than a small fountain located at the centre of the Hall.

Secondly, if it were a madrassa, it would be the most expensive education college in history because the entire building was covered with gold and other colours which came from precious gem stone (see Section 5.3.4.3).

Thirdly, all madrassa have paved surfaces in the courtyards instead of gardens. Although madrassa examples in Andalucia period have been hard to

Figure 27: Madrasa Al-Attarin in Fez, Morocco
(Source: Hillenbrand, 1994, p. 249)

Figure 28: Madrasa of Abu-Hassan in Sale, Morocco (1333 AD)
(Source: Hillenbrand, 1994, p. 246)
find, examples from other madrassa in Morocco built around the same time period had the courtyards paved (see Figure 27 and Figure 28). Hence to suggest that Court of the Lions was a madrassa would automatically mean that the courtyard area was paved at the time of Mohammad V period. This would go completely against the concrete archeological evidence that the four planting beds within the Court of the Lions were sunken by 3 feet for planting purposes (Section 5.3.4.9 Plants and Sunken Planting Beds).

5.3.3 Background information of Court of the Lions

The Court of the Lions is located at the center of the Palace of the Lions. The Courtyard has a dimension of about 52 feet x 94 feet (Moore, Mitchell, & Turnbull, 1988) which is about 28.50m by 15.70m (Grabar, 1978). Four magnificent halls surrounded this central Courtyard (Rabbat, 1985; Van Zuylen, 1999), one in each direction (see Figure 29). They are the Sala de los Reyes (Hall of the Kings) to the East, the Sala de las Dos Hermanas (Hall of the Two Sisters) to the North, the Sala de los Mocarabes (Hall of the Muqarnas) to the West, and the Sala de los Abencerrajes (Hall of the Abencerrajes) to the South. They create a balanced arrangement determined by the axially underlying the design of the courtyard (Dickie, 1992). This spatial arrangement of the Halls leads the view of the Court of the Lions not outward but inward. The inward looking creation also emphasized the seclusion and privacy (Hillenbrand, 1994) for Sultan Mohammad V. This inward focusing concept is further enhanced by its geometric composition and “each of the composition’s constituent parts forced
the observer into the consideration of ever smaller details” (Grabar, 1978, p. 185). This infinite division of geometric details provided visual pleasure.

The Court of the Lions has the strongest visual connection with the Hall of the Two Sisters. This Hall was the only part of the Court of the Lions complex to have been built by 1362 (Irwin, 2004). The Hall has a double exposure: to the south it overlooks the Court of the Lions, and to the north it commands the natural scenery framed by the Mirador de Lindaraja. The closer view from the Mirador consists of the Patio de Lindaraja, which is the vanished garden at the lower level; the further unrestricted view is of the planted northern slopes of the Sabika Hill, and the City of Granada stretching down the slopes of Albaicin Hill at
a distance (Dickie, 1992). The Sultan could relax and absorb the beauties of the unobstructed panoramic scene (Dickie, 1992). The Hall balances the two gardens of the Lions and Lindaraja, situated on different levels around its structure (Rabbat, 1985). This double-exposed position overlooking the two gardens is the most pleasant space in the Palace, reserved for its Master, Sultan Mohammad V (Dickie, 1979). The gardens, within the Court of the Lions and the vanished garden in the lower terrace (Patio de Lindaraja), were pleasure gardens arranged as such for people who enjoyed the sensuous experiences while serving the very earthly purpose (Rabbat, 1985) of relaxation. Like the water channels that unite the side chambers with the Court of the Lions gardens, the line of sight at the mirador combines the garden and landscape in the eyes of the beholder (Ruggles, 2000). Unfortunately the view from the Mirador de Lindaraja (Figure 30) was blocked later in 1527, by the insensitive implementation of the apartments of Charles V (Rabbat, 1985). The Hall of the Two Sisters was also famous for its visual climax, the muqarnas dome (see Figure 31). Upward of five thousand cells
cascading downward produced in their disciplined descent domes within dome. It has been considered as the most complex ceiling in the Muslim world and the peak of Islamic art on the peninsula (Dickie, 1992). The individual pieces of geometry of the murqarnas produces the overall stalactic and honeycomb effects (Irwin, 2004) when viewed from the center by looking up the dome.

The beauty of the Court of the Lions was based upon proportion and upon abstract geometric designs of unbelievable complexity (Irwin, 2004). Even the layout of the entire Palace of the Lions was built using the Nasrid method of proportioning with geometries started from the layout of the Court of the Lions (Fernandez-Puertas, 1997a). The ground plan of the Palace was constructed proportionally which also implied:

![Ceiling of the Hall of the Two Sisters](image)

**Figure 31:** Ceiling of the Hall of the Two Sisters
(Source: Site photograph of the researcher, 2007)
“…a corresponding proportional harmony in the elevations of the buildings and therefore in all their inner structural elements including arch, window, alcove, as well as in the proportional decorations on the walls of the rooms, galleries, patios, palaces and towers”

(Fernandez-Puertas, 1997a, p. 17)

Figure 32 to Figure 35 illustrates the proportional layout of the Court and Palace of the Lions which started with the layout of the Court. The proportional layout of the Palace and the Court of the Lions, together with its “high regards for light, colour, vegetation and water, displays to the full and the most dazzling facet of each element” (Prieto-Moreno, 1962, p. 18).

**Figure 32:** Proportional layout of Court of the Lions
(Source: Fernandez-Puertas, 1997a, p. 56)

**Figure 33:** Proportional layout of Palace of the Lions
(Source: Fernandez-Puertas, 1997a, p. 60)
5.3.4 The Elements of Court of the Lions

The known elements identified within the Court of the Lions are:

5.3.4.1 Columns and Arches with Perforated Screens

The rectangular courtyard is surrounded by a roofed, marble paved arcade of arches supported by 124 slender columns of white marble in single, double, or triple according to their place in the architectural design (Van Zuylen, 1999), and subtly placed in rhythms (Hillenbrand, 1994). These column were originally gilded (Irving, 1861) and have been compared to an imagined grove of 124 palm trees, most with double columns, around the oasis of the central fountain with its 12 lions (Villa-Real, 1981). The columns are so delicate that they give the impression that the arches were “the golden fringes of the spread of lace
suspended from the sky” (Cid et al., 1994, p. 39), because the garden plants in the middle prevented viewers from seeing how the pillars rested on their marble bases (ibid). These columns combine the “functional strength with an exquisite delicate appearance” (Ali, 1999, p. 102). Not only that the columns and the arches with perforated screens resemble the vegetation in marbles (Prieto-Moreno, 1973b), they also make a play of light and shadow (Ali, 1999; Prieto-Moreno, 1973b). It is the unbroken sequence of columns and arches with perforated screens with their complex rhythms around the court, which reinforce this magical image of Court of the Lions so universally admired (Bermudez Lopez & Galera Andreu, 1999).

5.3.4.2 Plaster Panels

The plaster panels were created by moulds. Once the negative mould was carved, repeated positive copies were made of it for square or rectangular panels. Each copy had a depth of 0.5 to 4 cm. While they were still wet, four little dabs of wet clay were stuck on to the backs of the copies, which were then stuck to the wall according to the sequence of the composition. The joints were then hidden by filling in with liquid gesso (Fernandez-Puertas, 1997a). Cardell-Fernandez suggested that “it was done with one or more layers of fine gypsum for hiding the plate joints and imperfections and to provide a uniform bright white base upon which the polychromy could be applied” (Cardell-Fernandez & Navarrete-Aguilera, 2006, p. 172). Once the whole panel was built up on the wall and it had dried off, several coatings of water with some dissolved lime were brushed over the surface to soften the rigidity of the pattern edges as well as the sharp planes
and angles, so as to become “transitional and gradual as they caught the changing light and the shadows” (Fernandez-Puertas, 1997a, p. 92). The application of lime also had an important purpose for damp resistance and will be discussed in Section 5.4.2 Scientific Analysis of Gypsum Mortars. The plaster panels were then painted with high quality pigments (ibid). See Section 5.3.4.3 below regarding colours on architecture for details. Each decorative plaster panel surrounded by its frame was normally designed in proportion to the wall. On occasion the decorative theme used to cover it was sometimes not composed expressly for that panel. In the cases when the pattern did not fit, it had to be cut off randomly “like a piece of silk or textile” (Fernandez-Puertas, 1997a, p. 92).

5.3.4.3 Colours on Architecture

The current sandstone look of the palace with touches of faded paint only here and there, is quite false to the medieval original (Irwin, 2004). During the Nasrid period, all architectural ornaments such as stone, wood and stucco, were gaudily painted with red, blue, green, white, black and metallic gold and silver and “made use of the textile concept” (Fernandez-Puertas, 1997a, p. 90). The combined effect of architectural details and polychromed colour appearance (Figure 36).

Figure 36: Artist rendering showing original colour on architecture
(Source: Bermudez Lopez & Galera Andreu, 1999, p. 114)
of the panels would have given the overall impression that the architecture resembles textile floating down from heaven. Acting with the reflected light, the patterned relief, details in carving and polychrome colour add “richness to the walls that varies with the hours of the day” (Fernandez-Puertas, 1997a, p. 89).

5.3.4.4 Inscriptions

Ornamental epigraphs were interwoven with the surface decorations located above the plaster panels and perforated screens. They consist of the repetitive emblems “Wa la Ghalib Illa Allah” which means “No Conqueror But Allah” (Grabar, 1978). The other most common location of the epigraph is just above the tile decoration found on the lower part of most walls at eye level (Figure 37) so that they are evident for the visitors and others to see and read them (Grabar, 1978). These inscriptions were in pure gold, lapis lazuli (blue) and foreign gem stone. They ground the blue gem stone and applied the dust in decorations (Garcia-Gomez, 1988). As mentioned in Section 2.3.3 Evidence from poetic inscription within Palace and Court of Lions, these inscriptions were intentionally designed and placed to give descriptions to the viewers at specific locations.

Figure 37: Epigraph at eye level
(Source: Site photograph of the researcher, 2007)
5.3.4.5 Tiles

The lower parts of almost all walls were covered with mosaic tiles generally white, red, yellow, blue, and green (Grabar, 1978). They were arranged in geometric tile patterns (Prieto-Moreno, 1973a). The upper part of the walls was left stuccoed and plain to “add reflected light to other decorated areas” (Fernandez-Puertas, 1997a, p.89). The surfaces of tile, together with plaster panels and perforated screens, make artificial foliage as rich and varied as that of plants, as they catch the light of the sun and the shimmering reflections from fountains and pools (Moore et al., 1988).

5.3.4.6 Pavilion

The appearance of the two pavilions, one at the east and west end of the Courtyard, gave the impression of tents supported by its slender columns when visitors stand beneath them (Casa Valdes, 1987). The combined effect of the play of the semi-circular and stilted arches, the use of mocarabes, which echoes the complexity of the famous ceiling inside the Hall of Two Sisters, as well as the positioning of the columns, suggested the sensuality and delight of nature and made these pavilions one of the most delicate expressions of the Nasrid interior (Bermudez Lopez & Galera Andreu, 1999).

5.3.4.7 Water

The use of water in the Palace of the Lions, as well as the rest of the Alhambra, belonged to a long and well-established tradition of paradisial gardens in palace settings (Grabar, 1978). The most common meanings associated with
water and its surrounding gardens is Paradise according to the Holy Quran (Grabar, 1978). The crossed-water axis, carries the water from four directions which flowed and converged on its central source, is a typical Islamic garden layout of the Chahar Bagh (Van Zuylen, 1999). The hierarchical order and the symmetrical patterns of the structure and the spaces in the Palace were applied to the uses of fountains and channels, creating an integrated architectonic ensemble of water and built elements (Rabbat, 1985; Ruggles, 1992). These fountains invoke “nature’s images inside the geometric enclosure” (Rabbat, 1985, p. 65). The flow pattern of water provided the physical continuity of the axes in the form of unbroken channels and flows towards the center of the Courtyard where the Fountain of the Lions is located (Rabbat, 1985).

5.3.4.8 Fountain of the Lions

The Fountain of the Lions formed the nucleus of the Palace (Rabbat, 1985). Prieto-Moreno mentioned the Court of the Lions was a place where “water was well respected right at the center of the Courtyard and can be viewed from every point within the Palace of the Lions” (Prieto-Moreno, 1973b, p. 69; Garcia-Gomez, 1988). The fountain was carved in white Macael marble (Bermudez Lopez & Galera Andreu, 1999; Sarro et al., 2006). Originally it was predominantly gold, which would stand out from the white marble background (Ali, 1999), but “they [the gold] have been scrapped” (Cid et al., 1994, p. 40) or pealed off.

The fountain recovered its original appearance in June 1965 with the removal from the haunches of the lions of the dwarf columns that had been

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added by Diego de Arcos in 1708. The upper basin was also removed for a similar purpose of recovering its original appearance (Dickie, 1992). Figural sculpture is very rare in Islam, but sculptured lions in abstract form became the integral parts of the fountain (Abdine, 1986). The fountain basin resting on the lions is 14th century. The Lion Fountain was expressly made for Sultan Mohammad V. Inscriptions around the base demonstrate the connection, for example, the 1st and the 12th verse of the poetic inscription around the fountain rim say that, “Blessed be He who gave the Imam Mohammad villas that adorned by their beauty all other villas” and “God’s blessings upon you and be immortalized reiterating celebrations and wearing down your enemies” respectively. The poem was by Ibn Zamrak (Ali, 1999), the Court Poet to Mohammad V. The poem also described the beauty of the garden. Furthermore, it praised and explained the complicated but perfect, hydraulic system which fills and empties the fountain (Bermudez Lopez & Galera Andreu, 1999). The water was engineered to flow both from the central fountain “outwards”, as well as traveling “inwards” from the fountains placed at the four ends towards the centre (Clark, 2004). The following show the complete twelve verses of the poem translated in English:

1: Blessed be He who gave the Imam Mohammad Villas
    That adorned by their beauty all other villas

2: Save this garden which contains wonders,
    That God forbids that beauty would find an equal to [them]

3: A pearly sculpture of translucent light.
    That enlightens with the flickering of gems all the surroundings

4: The silver is melting and then it flows between jewels.
To become analogous to them in beauty, that is to become pure white

5: The fluid appears to the gazing eye like solid.
So we did not know which of the two is flowing

6: Haven’t you seen that the water runs to the rim of the fountain prolonged over it the running channels

7: Like the lover whose tears overflow from his eyelids
But who conceals them in fear of a denunciator

8: Is it not [the fountain], after inspection, but a cloud
Pouring over the lions streams of water

9: It resembles the hand of the Caliph when it does
Shed in abundances, to the lions of Jihads, all sorts of favours.

10: You [the Caliph] who had watched the lions crouching.

11: And you the heir of the Helpers [of the Prophet] by merit
You have the heritage of greatness that disdains the mountains

12: God’s blessings upon you and be immortalized
Reiterating celebrations and wearing down your enemies

Scholars did not agree on whether the 12 lions dated to the 11th century or the 14th century, contemporary with the courtyard itself. Grabar argued that the lions may have belonged to an 11th century fountain (Grabar, 1978)36. However Fernandez-Puertas explained that:

“... the famous Fountain of the Lions was constructed proportionally to the magnitudes of the Palace of the Lions and its patio. This is perhaps the most conclusive proof that this sculptured fountain complex is exactly contemporary with the building of the Palace.”

(Fernandez-Puertas, 1997a, p. 17)

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Hence in his opinion, the fountain was not from the 11\textsuperscript{th} century. Figure 38 and Figure 39 show the proportional layout of the scale of the fountain relative to the Courtyard as well as the intricate and detailed design proportion of the Fountain of the Lions illustrated by Fernandez-Puertas.

5.3.4.9 Plants and Sunken Planting Beds

As mentioned in Section 2.2 Research Difficulties and Limitations, there have been few data on the original layout of Alhambra gardens (Bermudez Pareja, 1973). What was known for certain was the archeological evidence of 3 feet (80cm) sunken quadrants used for planting purposes mentioned earlier in Section 2.3.2 Archaeological Evidence. Jesus Bermudez suggested the depth of garden soil to be 1.5m (Pavon-Maldonado, 2000) at 3 feet
(80cm) below current elevation. The shape of the sunken garden beds suggested a notable reference for flat surface effects and straight lines (Ruggles, 2000). The garden may have once been a growing and perfumed floral carpet (Van Zuylen, 1999) with orange trees (Irwin, 2004). The carpet of flowers neither impede the view of the fountain (Irwin, 2004), nor the height of the planting prevented interference with the architecture (Irwin, 2004; Van Zuylen, 1999). The sunken vegetation and embedded water basins were intended for viewers seated on carpet or low cushions at walkway level. Such a position allowed the perspective of the viewers to skim the surface of the garden looking at the tops of the brightly coloured flowers reaching upwards to the sunlight rather than plants in profile or clumps of plants as in modern European and American gardens (Ruggles, 2000).

**5.3.4.10 2nd Storey Chamber**

Above the roof of the arcade, and also located on the south and north sides of the Court of the Lions, are the 2nd-storey chambers with *miradors* covered with *mashrabiyyas* (lattices of turned wood) that look down into the courtyard (Dickie, 1992; Ruggles, 2000). The chamber above the Hall of the Two Sisters has, in addition to its courtyard vista, a view in the opposite direction directed through the Hall of the Two Sisters to a mirador and onto a large garden of the Lindaraja and finally extending beyond the walls of the palace-city to the distant mountains (Ruggles, 2000).
5.3.4.11 Entrance Gateway (vanished)

In Nasrid time, the Palace of the Lions could only be reached from a private pedestrian street (Dickie, 1992). The original entrance of Palace of the Lions was on the facade of the south side of the Palace looking north (Irwin, 2004). Since the Palace of the Lions was designed for Sultan Mohammad V as a private palace, there was no grand entrance but only through a gateway opening off the street (Dickie, 1992). The South-west area outside the Palace of the Lions was destroyed for the construction of the Charles V palace (Ruiz Souza, 2001).

Figure 40: A perspective sketch showing the possible architectural layout with separate entrances of Palace of the Myrtles and of the Lions (Source: Hillenbrand, 1994, p. 451)

Robert Irwin commented that had Charles V not destroyed the facade of the two palace complexes (Palace of the Myrtles and Palace of the Lions), there would be no need for argument regarding the usage of the two palaces as there would certainly have been foundation inscriptions placed above or beside the entrances.
Figure 40 shows the possible look of the entrances to the two palaces without the presence of Charles V Palace.

5.3.4.12 Walkway

A marble walkway, in the form of an arcade, exists between the perimeter of the Courtyard and the surrounding four walls from the Halls. Slightly narrower paths are positioned adjacent to both sides of the four water channels leading from the arcade to the central Fountain of the Lions. Paths, or walkways, are essential design elements in Islamic garden. They are an integral part of the order and geometry of the design. Paths often provide the actual four-folded layout (Clark, 2004). The raised walkway gave the illusion that “the viewer walked on a carpet of greenery and flowers” (Ali, 1999, p. 105).

5.3.4.13 Light and dark and shadow effect

In general, architects of the Alhambra worked with light (Irwin, 2004) as well as gardens, water (ibid) and colour (Prieto-Moreno, 1973b). The lighting effect within the Court of the Lions was exploited (Prieto-Moreno, 1973a) by playing with the contrast between light and dark (Hillenbrand, 1994) as well as the shadow effects (Ali, 1999; Fernandez-Puertas, 1997a).

5.4 SCIENTIFIC STUDIES RELATED TO COURT OF THE LIONS

Since the turn of the 21st century, a number of scientific experiments were carried out within the Alhambra complex including the Court of the Lions. The
following are a few collected scientific experiments directly related to the Court of the Lions.

### 5.4.1 The decay of Machael Marble

Alhambra of Granada is one of many monuments where the white marble from Macael has been profusely employed (Bello et al., 1992). This marble comes from the Macael quarries in Almeria (Rodriguez-Gordillo & Saez-Perez, 2006) and has been described as having “excellent technical and artistic qualities” (Bello et al., 1992, p. 193). It was specifically used as the main construction material in the famous Courtyard of the Lions (Rodriguez-Gordillo & Saez-Perez, 2006). All elements such as the columns, pavement, and ornamental objects like fountains were made from this marble (Bello et al., 1992). Where the marble is located in exterior zones or in fountains, it is in “an advanced state of deterioration” (Bello et al., 1992, p. 193).

In general, polished surfaces like marble are not easily colonized by microorganisms, since outdoor exposed surfaces need to be initially weathered by environmental factors and synergetic action of wind, atmospheric acid corrosion (Urzi, 2004)

37, temperature, humidity, and the sun’s radiation (Song, 2001)

38. There is also the effects of the amount and rate of washing by rain, and stone surface wetness (MaGee, 1991). These factors influence a limited area of a structure or whose influence varies from place to place within the structure (MaGee, 1991). The environmental condition in Granada ruled out the action of

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38 Song cited in *Comparative Climatic Data for the U.S.*, 1999
gaseous and particulate atmospheric pollutants on the stone (Bello et al., 1992) because the City is located in the rural area with no high concentration of traffic or heavy industry. However other elements did have the effect. Thus the initial smooth and clean stone surface became progressively rough and more porous, and eventually led to the formation of micro cracks and fractures (Tiano, 2002). Out of all the above environmental factors, for the Court of the Lions, it was the continuous action of frequent thermal changes in conditions of extremes temperature that was the main cause of the alteration of the marble (Rodriguez-Gordillo & Saez-Perez, 2006). Considerable variation in temperature and relative humidity in the city of Granada (Bello et al., 1992) has been recorded with relative humidity ranges around 30% in July and 90% in January (Bello et al., 1992). Variations as much as 40% in the relative humidity have been recorded within one day (Bello et al., 1992). In a study carried out on the Alhambra during 1988 and 1989, temperature variations of 30°C in a day were recorded (Bello et al., 1992).

5.4.1.1 Deterioration of Marble Columns

The columns in the Court of the Lions are affected by different degrees of alteration, particularly in the form of superficial scaling and microcracks (Rodriguez-Gordillo & Saez-Perez, 2006). The characteristic alteration of the white marble consists of “intergranular loss of cohesion, which in many cases

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40 Bello et al. cited “Estudio sobre el estado de alteracion de la piedra de las columnas y fuente del Patio de los leones de la Alhambra de Granada y propuestas para su conservacion”, private report by the Grupo de Trabajo para la Conservacion de Obras de Peidra (1989).
includes crumbling and grain separation” (Bello et al., 1992, p. 193). The most common phenomena of deterioration is its exposure to continuous and extreme changes of temperature (Rodriguez-Gordillo & Saez-Perez, 2006). The extreme temperature changes contribute to the expansion/contraction cycles of the marble and eventually “lead to a continuous weakening of marble” (Siegesmund et al., 2000, p.181). This phenomena is most prominent on the sunny zone of the columns where “the stone is subjected to great temperature variations, in which the columns show decay and a serious loss of material, and the shady zone where there is little decay” (Bello et al., 1992, p. 194).

In order to further identify the causes of deterioration, marble samples were taken from the La Umbria quarry approximately 1500 m from Macael at the place known as Umbría de las Canteras (Rodriguez-Gordillo & Saez-Perez, 2006). The sample specimens of the material were subjected to accelerated heating-cooling cycles and the effects of these cycles on the physical and structural characteristics of the marble were measured by ultrasonic transmission velocity, hydric behaviour and mechanical resistance. The effects of the cycles were then examined on its granular cohesion of the material using an electron microscope (Rodriguez-Gordillo & Saez-Perez, 2006). The result showed the main mechanism of decay is scaling, as shown by the electron microscope images. The disaggregation by loss of intergranular cohesion is clearly visible after 200 cycles (Rodriguez-Gordillo & Saez-Perez, 2006). It was found that the degradation and loss of cohesion in the sample preferentially affect the most external zones (Rodriguez-Gordillo & Saez-Perez, 2006) of the marble. As well,
in the heating-cooling test cycles, a slight loss of material as powder, together with rounding of edges and corners of the sample blocks (Rodriguez-Gordillo & Saez-Perez, 2006) were observed.

In the same scientific article, Rodriguez-Gordillo mentioned the studies done by Galan et al.\textsuperscript{41,42} and Saez\textsuperscript{43} who examined the intimate relation between the type and degree of deterioration presented by each column and their corresponding thermal gradient. These studies indicated that the decay of the marble columns in Court of the Lions was due to:

“… [marble were] continuously exposed, as determined by the length of its exposure approximately 500 years to the sun”

(Rodriguez-Gordillo & Saez-Perez, 2006, p. 355)


5.4.1.2 Detailed study of levels of damages of columns

Figure 41: Diagram showing the levels of damages of columns
(Source: Saez-Perez & Rodriguez-Gordillo, 2004, pp. 80-81; edited by the researcher)

Figure 42: Levels of column damages
(Source: Saez-Perez & Rodriguez-Gordillo, 2004, p. 68; edited by the researcher)
The diagram (Figure 41) is a graphical summary of the damages of individual columns within Court of the Lions. It is indicated by the level of damage T1 (no damage) to T7 (maximum level of damage). Notice that the damage of the columns located along the arcade on the north are relatively more severe (T5 to T7 level) than the east, south and west arcade (T1 to T3 level). Figure 42 illustrates the classification of damages for each level.

5.4.1.3 Biodeterioration of the Lions

Biodeterioration is the name biologists give to “the damage that biological agents produce on various materials” (Nimis, 2001, p. 558). It is usually linked to environmental conditions. The most significant parameters affecting microbial growth are represented by physical factors, mainly “moisture, temperature, and light” (Saiz-Jimenez, 2001, p. 1). In general, stone works of art exposed to the environment are liable to be deteriorated by the action of biological agents such as bacteria, fungi, mosses (Sarro et al., 2006) as well as algae and lichens (Saiz-Jimenez, 2001).44 These biological agents draw energy from sunlight through photosynthesis (Nimis, 2001) and can develop well on exposed stone whenever a suitable combination of dampness, warmth and light occurs (Tiano, 2002). Biodeterioration can be found on “any vertical surface facing south [in the Northern Hemisphere] and washed down by rain” (Nimis, 2001, p. 559). As well, “surfaces exposed to direct sunlight, and having a slope that favours the rain run-

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off, are most subject to biocorrosion processes than other surfaces located in sheltered areas.” (Urzi, 2004, p. 443)⁴⁵

The deterioration of the lions (Figure 43) and the fountain is predominantly due to the presence in the form of biofilms (Sarro et al., 2006). It is found on all areas that are sufficiently moist and not subjected to direct sunlight (Tiano, 2002). The unfavorable surface growing conditions, due to the direct exposure to sun irradiation and the “extreme” climates, pushes the microorganisms to live beneath in more protected layers. As a result the biofilm eventually causes “the detachment of an external part of the material through cycles of expansion and shrinking of the extracellular polymeric substances EPS” (Urzi, 2004, p.445)⁴⁶, as well as by cracking of the base material due to the “wedge” effect of microbial entry in the pores or microfissures of the stone, resulting in physical

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damages (Sarro et al., 2006). This phenomenon is known as Scaling (Urzi, 2004). It can be seen clearly on the colonisation of the surface of Lions 5 and 9 by the presence of mosses and fungi (Sarro et al., 2006). Two other forms of physical damage to marble are microbiologically related alterations of the marble. The first kind happens when they grow into the pores of the marble which has been exposed for any length of time to dry environments. Their growth causes a pressure that crumbles and pulverizes the material (Urzi, 2004). The second kind is the bioprecipitation of mineral phases which form a patina and crust (Urzi, 2004) on surface of the marble.

5.4.1.4 Protection Recommendation of Machael Marble

The above scientific studies of the alteration of the white marble used in the Alhambra are caused, fundamentally, by the great environmental variations. Weathering causes disaggregation of the material which leads to a serious loss in hardness and mechanical strength (Bello et al., 1992). The decayed material is capable of absorbing a greater amount of water and possibly accelerating the decay process due to the freeze/thaw cycles (ibid). The cracking of the marble also encourage further deterioration of the marble by means of the biodeterioration process. For the conservation of the Machael white marble in the Alhambra, protection is needed from solar radiation where the treated material is “exposed to high levels of sunlight” (Bello et al., 1992, p.199). The screening

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48 Urzi cited Danin & Caneva. International Biodeterioration. 26, 397-417
would limit the exposure of the marble to intense solar radiation as well as
minimizing the extreme changes of temperature. It was also recommended that
simple screening of the sunlight helps to “eliminate all microorganisms, control
over temperature and humidity which helps to limit the growth of bacteria and
fungi” (Nimis, 2001, p. 562).

5.4.2 Scientific analysis of Gypsum Mortars

A plaster cast technique was used for the creation of the plaster panels
throughout the Palace of the Lions (Cardell-Fernandez & Navarrete-Aguilera,
2006). Only the best quality gypsum was used to model the stucco (ibid). A
special “characteristic technology was used for applying mortars in this
The technique was to add slaked lime to gypsum mortars to make the mortars
“more resistant to the damp by means of calcium carbonate formation” (García-
Bueno & Medina-Flórez, 2004, p.89). The slake lime also helps to delay the
mortar setting, thus offering more time to carve the reliefs in the decoration (ibid).
The addition of slaked lime to the mortar ultimately makes the mortar harder
through carbonation (ibid).

5.4.3 Scientific analysis of Colour Pigment

In general the current whiteness of the gypsum mortar of Nasrid
decoration is not the original representation because the original polychromy
stucco were “restyled when Christian kings decided to inhabit the Alhambra and
remodeled or covered original, deteriorated polychromy with white paint”
(Cardell-Fernandez & Navarrete-Aguilera, 2006, p. 163), over the years (García-Bueno & Medina-Flórez, 2004). However, a detailed study of the plasterwork shows that the polychromy was “very carefully executed, using high-quality pigments” (García-Bueno & Medina-Flórez, 2004, p. 78) during the Nasrid period. The polychromy made the decoration richer, to highlight the relief, to integrate all the wall decoration materials and to highlight the carved motifs (García-Bueno & Medina-Flórez, 2004).

Within the Court of the Lions, samples were analyzed along the North, East and West interior wall of the East Pavilion. Traces of colours from different pigments were found including “dark emerald, light emerald, red, yellow-green, intense blue, dark blue and violet” (Cardell-Fernandez & Navarrete-Aguilera, 2006, p.165). Some pigments, red lead and malachite in particular, were “severely decayed through introduction of chloride-based materials, resulting in discolourations” (Cardell-Fernandez & Navarrete-Aguilera, 2006, p.161). Lapis lazuli, a blue precious gem stone which was as expensive as gold, was used in decorative architecture and was restricted to the most prestigious palaces (Cardell-Fernandez & Navarrete-Aguilera, 2006)50 such as the Alhambra.

Gilding gives richness to the walls and was used in all palaces excluding the Muslim House of the Partal Palace (Cardell-Fernandez & Navarrete-Aguilera, 2006) within the Alhambra. In a practical term, the sheet of gold is so thin, less than 10 micro millimeter in thickness, it would be hard to handle. To avoid wasting the expensive gold leaf, it was first applied to a tin sheet, a support that

is more flexible, consistent and easier to handle (Cardell-Fernandez & Navarrete-Aguilera, 2006).

5.5 COURTYARD STUDIES

5.5.1 Trees in Courtyards

“... whenever there is vegetation and/or deep shading provided by architectural elements such as porticoes, there is a better cooling performance.”

(Reynolds, 2002, p. 67)

A courtyard with distinct boundaries, limited access to other landscapes, and manicured plants, is one of the most controlled form of landscape intimately related to its surrounding building (Reynolds & Lowry, 1996). It represents “an attempt to bring the forces of nature under partial control” (Reynolds, 2002, p. 79). As well, it is the “primary contributor of light and air to the building” (Reynolds & Lowry, 1996, p.125), and it plays a major role in a building’s energy consumption and in its thermal comfort (ibid). Its thermal performance is mainly affected by the solar radiation penetration on the internal envelope (Muhaisen, 2006). A courtyard takes full advantage of the solar radiation to facilitate reflection of light into internal spaces when it is desirable and to avoid it when radiation may cause discomfort (ibid). Ideally, courtyards receive “maximum radiation in winter and minimum in summer” (Muhaisen, 2006, p.1740).

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51 Reynolds cited in a study of ten Seville courtyards by Perez-de-Lama and Cabeza (1998). Exact title of article was not mentioned.
In general, shading, the avoidance of heat gain, is the “first rule of thermal comfort in summer” (Muhasilen, 2006, p.1731). Without shading, building surfaces absorb solar radiation, raising the surface temperature above the ambient air and adding to the cooling loads due to the air temperature and humidity (Muhasilen, 2006). It is preferable to intercept the solar radiation before it strikes the building surface for effective shielding of the building from the sun (ibid). Tree leaves help to absorb most of the solar radiation with very small reflected solar radiation (Alvarez et al., 2002). During day time, tall trees with a wide canopy rising above the roof (Alvarez et al., 2002) in the courtyards help to “shade the walls and the ground from the intense direct solar radiation of summer” (Safarzadeh & Bahadori, 2005, p. 89), therefore shading the site reduces the overall surface temperatures (Alvarez et al., 2002). During late evening and night time, trees continue to prevent the buildings from overheating. The upper part of the tree’s leaf canopy loses heat to the sky by transpiration while the leaves cool the air around them. The air tends to be heavier and sinks into the courtyard (Alvarez et al., 2002). The tall trees also create a semi-barrier between the courtyard air space and the ambient air above (Alvarez et al., 2002). They allow wind to pass through their canopy (Reynolds, 2002) yet reduce air exchange on windy days (Alvarez et al., 2002). As well, the trees help to regulate the evaporative cooling process in courtyard which will be described in details in Section 5.5.3 Evaporative Cooling Strategies in hot-dry climates.

A sensitivity analysis carried out for different tree height to facade height ratio reveal that the energy saving limit is 60% (see Figure 44). When the height of the tree is “equal to (more or less) facade height then the energy saving is the highest and taller tree heights are not relevant” (Alvarez et al., 2002, p. 4).

![Figure 44: Energy saving relative to tree and facade height (Source: Alvarez et al., 2002, p. 5)](image)

Besides the use of trees, the cooling effect in courtyards is further aided by the following:

- The use of massive walls of courtyard buildings which help to act against the extreme heat by day and cool by night (Carrasco & Reynolds, 1996)

- The use of arcades which separate the courtyard walls from the rooms of the building which helps to make the rooms are much cooler with the arcade as a transition zone (Reynolds & Lowry, 1996)
• The employment of the evaporative cooling strategies (see Section 5.5.3 Evaporative Cooling Strategies in hot-dry climates)

5.5.2 Characteristics of wide shallow courtyard

Courtyard proportions (see Figure 45) range between two extremes: wide and shallow, or narrow and deep (Reynolds & Lowry, 1996). The Court of the Lions belongs to the former category. A wide and shallow courtyard “will often be a sunny collection of plants and water while the narrow, deep courtyard will be shady and more reverberant for sounds of water and birds” (Reynolds & Lowry, 1996, p. 124). A shallow courtyard admits more sun in both summer and winter and admits more wind (Reynolds & Lowry, 1996). The more shallow the courtyard, the more the floor sees of the sky rather than the walls and so “the more radiant heat loss by night” (Reynolds & Lowry, 1996, p. 128). Without intervention by either plants or inhabitants, the shallow courtyard in a hot-dry climate will be harder to cool on a summer day, but probably warmer on a winter day (ibid). Typically a shallow courtyard with trees has a skyline that “permits entry of some direct sun in winter and coolest in summer” (Reynolds & Lowry, 1996, p.134). Hence the shallow courtyard has the best performance in both seasons (ibid).
5.5.3 Evaporative Cooling Strategies in hot-dry climates

The inland areas of Andalucia has dry and hot summers with highest temperatures ranging from 38°C to 42°C in the late afternoon and a lows of 16°C to 20°C in the early mornings in the month of July, August and September (Carrasco & Reynolds, 1996). During the heat waves, high temperatures during the late afternoon can go to 44°C to 45°C with the lows in the early mornings in
the mid-20s. This poses a difficult cooling problem. On the occasional overcast days the heat can be unbearable (Carrasco & Reynolds, 1996).

A courtyard in hot-dry climates employs the evaporative cooling strategies (Reynolds & Lowry, 1996) by making use of the low humidity of the air (Carrasco & Reynolds, 1996) to allow the absorbent of water to promote evaporation within it. In the zone marked “evaporation,” (see Figure 46) these outside conditions can still produce comfortable cool conditions within buildings, if evaporative cooling is skillfully employed (Reynolds & Lowry, 1996).\(^{54}\)

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\(^{53}\) Reynolds explains: In the zone marked “evaporation,” these outside conditions can still produce comfortably cool conditions within buildings, if evaporative cooling is skillfully employed (based on Milne and Givoni 1979, p. 107).

\(^{54}\) Reynold et al. cited in Milne and Givoni 1979, p.107. Title of article was not mentioned.
Both water and plants are used for evaporative cooling process (Abdelbaki Mohamed, 1999) to add humidity to the dry air, which helps to “enhance comfort conditions” (ibid, p. 6) within the courtyard. Psychological reinforcement of cooling in summer is provided by the “sound and sight of water” (Carrasco & Reynolds, 1996, p. 93), with the plants that provide “shade and motion in slight breezes” (Reynolds & Lowry, 1996, p. 135).

A water feature in the middle of a patio and the watering of plants in the patio allow the slow release of water (Carrasco & Reynolds, 1996). Where water is available in plenty, it may be sprayed on the courtyard floor during the afternoon which also produces evaporative cooling (Abdelbaki Mohamed, 1999). Hence, plants do not only add considerable appeal, but they are important as catalysts for general watering, facilitating evaporative cooling (Reynolds & Lowry, 1996). The evaporation process of water from the leaves, known as evapotranspiration, causes significant cooling of the leaves and the air in contact with them (Alvarez et al., 2002).

As mentioned in Section 5.5.1 Tree in Courtyards, the leaves of trees intercept the solar radiation before it strikes the building. Thus trees are always at a controlled temperature as they “dissipate the heat absorbed by evapotranspiration” (Alvarez et al., 2002, p. 4).

The courtyard floor is the most likely surface to help in the evaporative cooling process because it is a natural collecting place for water (Reynolds & Lowry, 1996). It also has the highest tendency for the coolest air to accumulate at the floor level (ibid). Since the capacity of air to absorb moisture rises with
increased dryness, evaporation will most rapidly occur in the driest air. Hence the dampness of the courtyard floor in dry air succeeds in evaporative heat exchange (Reynolds & Lowry, 1996, p. 128).

In summary, the evaporative cooling strategy “uses water to raise the moisture content of surrounding air, from bodies of water, fountains or evapotranspiration of vegetation, inducing cooling of the air and adjacent surfaces” (Brophy et al., 2000, p. 13). With the trees, flowers, shrubs and a pool of water, the courtyards “…created a micro-environment, a few degrees lower in air temperature and slightly higher in relative humidity” (Safarzadeh & Bahadori, 2005, p. 89). In hot-dry climates, this “cooler and more moist air represents increased comfort” (Reynolds & Lowry, 1996, p. 128).

To increase humidity at a site, Vivienne Brophy recommended the following (Brophy et al., 2000, p. 14):

1. Increase the water retention of surfaces and reduce drainage
2. Provide a means of evaporative cooling using fountains, ponds, sprinklers and sprays, etc.
3. Use vegetation in preference to hard landscaping materials where possible
4. Use low planting to reduce moisture evaporation from ground

5.5.4 An Evaporative Cooling Example: EXPO ‘92 Seville

Evaporative cooling has been used to reduce temperatures in Southern European countries for centuries, from the Gardens of Alhambra to the 1992 Seville EXPO. Water evaporation absorbs a considerable amount of heat energy,
about 590 calories per cubic cm of water evaporated (Brophy et al., 2000). Over one day, a single large tree can:

“… transpire 450 litres of water and diverts 230,000 Kcal of energy away from raising air temperatures which is equivalent to five average air-conditioner units running for 19 hours each”

(Brophy et al., 2000, p. 14)

Figure 47: Evaporative cooling at Alhambra, Granada and at EXPO 92, Seville
(Source: Alvarez et al., 2002, p. 2)

An example of the effective use of evaporative cooling is the planning for the EXPO '92 in Seville (Figure 47), Spain, using natural cooling elements like vegetation and water (Brophy et al., 2000). The tree and shrub formations, combined with the flow and play of water, conditioned the air by absorbing the sun's energy. Leaves permitted water evaporation to cool the air and increased humidity from 20 or 30 percent to between 50 and 60 percent (Scurr, 1991). Vegetation species of different heights were used to maximize the filtration of air at different levels. Planted screens were designed to channel prevailing winds

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55 Brophy cited in Hough M, Cities and Natural Process, Routledge, 1995
into the site, enhancing their cooling. Water was used throughout the site in fountains, water walls, sprays, cascades, ponds (Brophy et al., 2000). Combined with a welcome reduction in temperature of perhaps as much as 22°C (40°F), this modification in humidity over the whole 251-hectare (620-acre) site justified the description "microclimate," and surpassed even the accomplishments of the Arabs in their cool, fragrant gardens (Scurr, 1991). Studies prior to the construction of the EXPO, and further in-use assessments have shown that comfortable external environments were achieved by the natural means described above (Brophy et al., 2000).

5.6 Descriptions of vegetation and shade in the Holy Quran and Hadith

The descriptions of Paradise in the Holy Quran and Hadith provide vivid impressions of greenery, trees, lushness, gushing fountains, delicious fruit, and unimaginative beauty (Nassar, 2002; Schimmel, 1976). The Quran describes Paradise (al-jannat “the Garden”) in the form of a garden (Dickie, 1976). The range of descriptions used with jannat indicates a place “not only blissful and eternal, but also a refuge, a sheltered and secure retreat” (Clark, 2003, p. 85).

Out of all the garden elements of Paradise mentioned in the Holy Quran, namely: water, shade, vegetation, walls, gates, pavilions and layout of Paradise garden in 164 different verses (Nassar, 2002), only vegetation and shade will be examined in more details in the following sections. As mentioned earlier, the Islamic garden draws its vocabulary from the description of Paradise in the Holy Quran and Hadith. Hence, logically speaking, the heavenly descriptions of all the
elements should be reflected and used as design elements within the Court of the Lions. As expected, all the other garden elements above are already present within the Court of the Lions. These known elements were already described in details in Section 5.3.4. By knowing the descriptions of vegetation and shade elements in Paradise, it is possible to generate clues to the missing elements within the Court of the Lions from the metaphysical stand point.

5.6.1 Description of Vegetation in Paradise

In the Holy Quran there are superb vocabulary in many Surahs (Arabic word meaning “Chapters”) that describes about trees, shrubs and vivid impression of greenery, as well as lushness of plants which provide food, colour and shade (Nassar, 2002). Plants mentioned include: sweet-smelling plants (Surah 55:12); grapes and nutritious plants (Surah 80:28); orchards (Surah 27:60); green crops, dates, grapes, olives, pomegranates with variety (Surah 6:99); green and luscious pasture (Surah 87:4); talh (banana) trees with flowers (or fruits) (Surah 56:29); produce (vegetation) of various colours (Surah 35:27); date-palm and vines (Surah 2:266); grapes (Surah 16:11); fruit of every kind (Surah 13:3); corn (Surah 16:11); herbs (Surah 55:6); and trees (various verses); just to name a few.

The following are selected descriptions regarding vegetation in Paradise:
5.6.1.1. All plants have fragrant aromas in Paradise

All aromas have been created as blessings to please the senses of the believers. The Quran mentions “sweet-scented plants” in Surah 55: 12. As well, from Hadith, plants in Paradise are known by their beautiful scents:

“Henna [a dye and scent] is the chief scent of the Garden… When Allah created the Garden He filled it with the scent of sweet basil, and surrounded the sweet basil with the scent of henna…”

(Yakup, 2005)

The scent of Basil in this world is only a pale reflection of those in Paradise and Allah knows best (Yakup, 2005). It is worth mentioning that besides plants, every place is scented with sweet aromas, even the soil of Paradise has a fragrance of saffron (ibid).

5.6.1.2. Fruits are plenty and are very easy to reach in Paradise

“Verily, the Muttaqun [the pious] shall be amidst shades and springs. And fruits, such as they desire. ’Eat and drink comfortably for that which you used to do.’” (Surah 77: 41-43)

“Since its [blissful] shades will come down low over them, and low will hang down its clusters of fruit, most easy to reach.” (Surah 76: 14)

“And by water flowing constantly, And fruit in plenty, Whose supply is not cut off (by change of season) nor are they out of reach.”

(Surah 56: 31-33)

56 Yakup cited in Mukhtasar Tadhkirah al-Qurtubi, p. 342/619.
57 Saffron is a spice and dyestuff obtained from a valuable plant. It has a vanilla-like aroma (Yakup, 2005)
5.6.1.3. Unimaginable plants and fruits in Paradise

In Paradise, believers will witness Allah’s incomparable and endless creation where everything is possible (Yakup, 2005). For example, the fruit of the trees in Paradise “will resemble rubies, diamonds, sapphires and other precious stones but become edible when people pick them” (ibid, p. 50). This may explain why Muslim gardeners love to acquire foreign plants from distant lands in an attempt to experience this “unimaginable” feeling through the growing of these less known plants with great interest and appreciation.

5.6.1.4. Natural beauty of Paradise

Allah created the human spirit to take pleasure in “form, symmetry, beauty, purity, order, harmony of colour, in short, in perfection. All colours and sights in nature correspond most to this delight in the human spirit.” (Yakup, 2005, p. 48). The places that people have a sense of well-being and happiness always associate with natural beauty and full of vegetation such as woods and forests with clean air and open space as well as near to water. Conversely places far from natural beauty are associated with no sunshine and no fresh air (ibid). Human beings “look for natural beauty because Allah has created us to take pleasure in the beauties and blessings of Paradise, whether a person is aware or not” (Yakup, 2005, p. 48).

5.6.1.5. Trees in Paradise

Trees have been created to be of great benefits for the earth and they are a blessing offered by God (Yakup, 2005). We like to be in places where there are
trees and green spaces and enjoy looking at photographs or paintings of such places (ibid). Trees have been created for human pleasure with their wonderful appearances, type and colour variations, as well as the associated pleasing shade (ibid). The idea of shade in Paradise is described by the verses shown in Section 5.6.2.1 Perpetual Shade in Paradise.

5.6.1.6. Specific description of date palm in Hadith

When someone asked the Prophet (p.b.u.h.) whether there are dates in Paradise, the Prophet (p.b.u.h.) replied:

“Yes, there are dates… the dates [palm] of the Garden have golden branches. They have golden shoots. They have leaves as beautiful as the finest clothing anyone has ever seen. There are golden bunches of dates. Even the stalks of these bunches of dates are gold. At the base of each golden date are sticky scales. They have fruits like giant jars, softer than foam, sweeter than honey.”

(Yakup, 2005)58

5.6.2 Description of Shade in Holy Quran and Hadith

In the Holy Quran, Paradise has been described as having a “perfect temperate climate” (Clark, 2004, p. 24) where the blessed shall be shaded by “thornless lote-trees” (Surah 16: 28) as well as “palms and vines” (Surah 2: 266). Shade is a significant feature in Paradise gardens (Nassar, 2002). In the Quran, God promises shade to his faithful believers as a blessing (Yakup, 2005). “Spreading shade” is an expression posed in the Quran as part of the reward that

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awaits the believers and righteous (Nassar, 2002). There are many verses that mention shade in the Quran similar to the following:

“But those who believe and do deeds of righteousness, We shall soon admit to Gardens, with rivers flowing beneath - their eternal home: Therein shall they have companions pure and holy: We shall admit them to shades, cool and ever deepening.” (Surah 4: 57)

From Hadith, the Prophet (p.b.u.h.) mentioned the enormous dimensions of the trees in Paradise. He described a tree by mentioning its shade:

“In the Garden, there is a tree under whose shade a rider could travel for a hundred years without covering [the distance] completely”

(Yakup, 2005)

The most famous phrase of all relates to water and shade which says: Jannat tajri min tahtiha al-anhar. From an English word-by-word translation of the Quran (Study the Noble Quran: Word-for-word, 1999): Jannat means “Gardens”, tajri means “flowing”, min tahtiha means “under which”, and al-anhar means “streams”. While this phrase was commonly known as “Gardens underneath which rivers flow”, this phrase should be interpreted as “Gardens with rivers flowing under them” (Yakup, 2005) or “Gardens with rivers flowing beneath” (Al-Shimemeri, 1994) based on the above word by word translation. The use of the word “rivers” emphasizes the abundance of water in Paradise as blessings from God (Yakup, 2005). This phrase is frequently used as expression for the bliss of

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59 Yakup cited in Sahih Muslim; narrated by Sahl ibn Sa’d.
the faithful, and occurs more than thirty times throughout the Quran (Brookes, 1987; Clark, 2003; Nassar, 2002).

Amongst the verses about shade, the following are selected quotations from Quran which specifically describes the shade condition in Paradise:

5.6.2.1. Perpetual Shade in Paradise

“gardens of perpetual bliss, which they shall enter together with the righteous from among their parents, their spouses, and their offspring; and the angels will come unto them from every gate [and will say]: ‘Peace be upon you, because you have persevered!’ How excellent, then, this fulfillment in the hereafter!” (Surah 13:23-24)

“The parable of the Garden which the righteous are promised - beneath it flow rivers: perpetual is the enjoyment thereof and the shade therein: such is the end of the Righteous; and the end of Unbelievers in the Fire.” (Surah 13: 35)

“In shade long-extended” (Surah 56: 30)

5.6.2.2. No extreme heat or cold in Paradise

“Reclining in the [Garden] on raised thrones, they will see there neither the sun’s [excessive heat] nor [the moon’s] excessive cold” (Surah 76: 13)

“Nor are the [chilly] shade and the [genial] heat of the sun” (Surah 35: 21)

5.6.2.3. No extreme light and darkness in Paradise

“Nor are the depths of darkness and the light” (Surah 35: 20)
5.7 SITE VISIT: A DAY IN THE COURT OF THE LIONS

The researcher paid two visits to the Court of the Lions on July 5, 2007 between 12:30pm to 5:40pm and 9:30pm to 11pm. The two main purposes of the two visits were to experience the space of the Courtyard first hand as well as to take high quality and high resolution photographs of different elements within the Courtyard. The space was experienced in a variety of ways including walking and sitting at different locations within the Courtyard, trying to look at the Courtyard from different viewing angles. A total of over 500 images and 5 videos were taken from a number of these locations. Special attention was paid when taking the panoramic images at the West Pavilion which included both standing\textsuperscript{60} (Figure 48) and sitting\textsuperscript{61} (Figure 49) positions. Attention was also given to the damage caused by the deterioration of columns on the sunny (south-facing) side along the north facade (Figure 50). Figure 51 shows the columns along the south facade which had no visible marble deterioration.

\textsuperscript{60} Eye height of researcher in standing position: 59 inches (149.8 cm)
\textsuperscript{61} Eye height of researcher in sitting position: 28.5 inches (72.4 cm)
Figure 48: Viewing from West Pavilion in Standing Position (Time: 2:53pm)

Figure 49: Viewing from West Pavilion in Sitting Position (Time: 3:04pm)
Figure 50: North and South-Facing sides of columns along North Facade (Time: 2:46 pm)

North-facing side of the columns (no visible marble deterioration)

South-facing side of the columns (visible marble deterioration)

Figure 51: North and South-Facing sides of columns along South Facade (Time: 3:17 pm)

North-facing side of the columns (no visible marble deterioration)

South-facing side of the columns (no visible marble deterioration)
This chapter focuses on analyzing the pieces of evidence collected in the previous chapter with respect to the investigation of the three missing variables namely: “shade”, “tree form and arrangements”, and “shrub types and arrangements” variables. This chapter followed the investigation procedure and research logic described in Section 3.4. As shown in Figure 11, the first variable under investigation begins with “shade”, then followed by “tree form and arrangements” and finally “shrub types and arrangements”.

6.1 THE INVESTIGATION OF “SHADE”

The determination of “shade” or “no shade” would be crucial as this variable alone could readily affect the outcome of the garden atmosphere. Furthermore the other two variables were dependent and closely related to the findings of the “shade” variable.

First, the investigation started by mapping out all the evidence as regards to shade (or no shade). Second, the collected evidence were analyzed and then arranged, or re-arranged, in iterations using the concept mapping technique until all the evidence could be rationalized and the interrelationships amongst the evidence defined. During the iteration of the concept mapping process, grounded theory was also employed at the same time looking for a common theme of “shade” or “no shade” amongst the evidence.

showed the finalized version of the concept map with a clear pattern of shade emerging from the evidence. This map acted as a visual summary of the
evidence related to shade. The diagramming of evidential relationships allowed the shade variable to “speak for itself”.

**Figure 52: Concept Map of Shade**

The following is a literal summary based on the above concept map of Shade. The evidence supporting shade was classified into the following categories: Site Evidence (Section 6.1.1), Islamic Garden Evidence (Section
6.1.2), Metaphysical Evidence (Section 6.1.3) and Microclimate Evidence (Section 6.1.4) as shown in Concept Map above.

6.1.1 Site Evidence

6.1.1.1 Marble columns deterioration:

This was derived from evidence in Section 5.4.1.1 and 5.4.1.2. The decay and serious loss of material on the sunny zone of the columns, the continuous action of frequent thermal changes due to the temperature extreme, as well as the diagram from the detailed studies of individual column all suggested that the marble deterioration was caused by the absence of shade on the sunny zone for marble protection.

The idea of the absence of shade was further supported from studies carried out by Galan et al. and Saez-Perez (Rodriguez-Gordillo & Saez-Perez 2006)\(^\text{62}\). Their studies indicated that the decay of the columns was due to continuously sun exposure for approximately 500 years. These studies were published between 1990 and 2004. A quick subtraction of 500 from 1990 and 2004 would get the year 1490 and 1504 respectively. In other words, the Court of the Lions could have undergone dramatic environmental change around 1490

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\(^\text{62}\) Rodriguez-Gordillo & Saez-Perez cited in:
and 1504 which initiated the deterioration process. By further scrutinizing on the years, namely 1490 and 1504, it seemed to indicate that the “dramatic change” most likely happened between 1492, when the Reconquista started the initial renovation of the Alhambra (Section 2.2), and 1494 when Munzer arrived at the Alhambra who was the first recorded visitor. Munzer described the Court of the Lions was paved with marble slabs (Section 3.1). By piecing this evidence in sequence of events, it would be logical to describe that the “dramatic change” of environment started when all trees originally planted to create the shade within the Court of the Lions in Arab time were cut down during the initial renovation in 1492. When Munzer arrived in 1494, he saw the newly renovated Courtyard with marble paving slabs and all traces of plants were removed. Since then the Courtyard had no shade. The marble columns, and the Lions in marble, were constantly exposed to the strong sun. Eventually deterioration started on the sunny zones of the columns due to continuous thermal extremes happening over 500 years. The cracks on the Lions encouraged the growth of moss and fungi which caused further damages to the marble (see next Section for details).

6.1.1.2 Mosses and fungi growing on Lions

This was derived from the evidence in Section 5.4.1.3 and 5.4.1.4. The surface of the lions 5 and 9 were colonized by mosses and fungi (Sarro et al., 2006). Further physical damage was done by the microbes growth deep into the micro-cracks which eventually caused detachment of external parts of the marble. It was recommended that simple screening of the sunlight would help to limit the
growth of bacteria and fungi (Nimis, 2001). Hence the presence of shade in Court of the Lions would be important.

**6.1.1.3 Screening from high level of sunlight**

This evidence came from Section 5.4.1.4. It was recommended that protection would be needed from solar radiation where the marble is exposed to high levels of sunlight (Bello et al., 1992). This suggested that shading from trees within the Court of the Lions could help to screen and to absorb the solar radiation before the sun rays reached the surface of the marble hence reducing temperature extremes on the marble.

**6.1.1.4 Slaked lime in mortar**

This was derived from Section 5.4.2, that the usage of slaked lime in gypsum mortar was to make the mortar more resistance to moisture. It is indirectly related to shade and to Human Comfort. See Section 6.1.4.2 Increase Human Comfort for details which describe the relationships amongst slaked lime, evaporative cooling strategy and the presence of shade from trees.

**6.1.2 Islamic Garden Evidence**

**6.1.2.1 Shade is one of the principal elements**

This evidence came from Section 5.1 where it said no matter where the Islamic garden is located, shade and water are the two most important design elements within the garden. Hence shade from trees is a “must have” item in Court of the Lions.
6.1.3 Supporting Metaphysical Evidence

6.1.3.1 Perpetual Shade in Paradise

This evidence came from Section 5.6.2.1. In describing Paradise – the metaphysical model for Islamic gardens – it was mentioned in the Quran that there is perpetual shade (Quran 56:30) and no extreme heat from the sun or bitter cold (Quran 35:20-21; 76:13). Indeed, shade is a significant feature in paradise gardens. The description of shade can be found throughout the Quran as a reminder of the reward and encouragement for people to do good deeds. This suggests that the Court of the Lions, being an Islamic garden, needs to reflect the Quranic idea of shade.

6.1.3.2 Size of shade of a tree in Paradise:

This evidence came from Section 5.6.2. It was mentioned in Hadith that in Paradise, there is an enormous tree so large that a rider could not cover the distance of its shade in one hundred years. This sentence seems to imply that shade in Paradise seem to cover an infinitely large area. Hence this Hadith supports the idea that Paradise has permanent shade (see Section 6.1.3.1 above).

6.1.3.3 “Gardens underneath which rivers flow”

This verse was mentioned over thirty times in different chapters in the Quran (Nassar, 2002). It suggested that water should be protected from direct exposure to sunlight for water conservation according to the Holy Quran. This turns into the physical reality of gardens located in very different parts of the
world when Muslim gardeners use trees to create shade for solar protection of water features. Thus the Court of the Lions should have similar design ideology for using shade from trees to protect water bodies.

6.1.4 Supporting Microclimatic Evidence

6.1.4.1 Important roles for trees in courtyard

This evidence came from Section 5.5.1. Trees in courtyards not only help control solar gain in the building, but also shade the site, reducing surface temperatures (Alvarez et al., 2002). The leaves of trees intercept the solar radiation before it strikes the building and dissipates the absorbed heat by evapotranspiration (ibid). The tall trees with a wide canopy, rising above the roof, not only provide the shade but create a semi-barrier between the courtyard and the ambient air temperature above. This reduces the air exchange on windy days (ibid.). This suggested the important role of trees in a courtyard to provide more than shade, but also to help to “slow down” the rate of evaporation during unfavourable or extreme conditions such as windy days.

6.1.4.2 Trees make courtyard coolest in summer

This evidence came from Section 5.5.2. A wide and shallow courtyard, like the Court of the Lions, would admit more sun in both summer and winter as well as more wind (Reynolds & Lowry, 1996). A shallow courtyard with trees makes the courtyard coolest in summer with direct sun in winter (Reynolds & Lowry, 1996). This suggested the use of trees in courtyard for the “all year round” purposes.
6.1.4.3 Increase human comfort

Evaporative cooling strategy uses water features and evapotranspiration of vegetation to raise the moisture content of surrounding air (Brophy et al., 2000). In order to ensure that the increase of moisture within the Court of the Lions by the evaporative cooling strategy would not affect the structure of the building, the Arabs used slaked lime in mortar to make the gypsum mortar more resistance to dampness. Since the capacity of hot dry air to absorb moisture rises with increased temperature, evaporation will most rapidly occur in the hottest air (Reynolds & Lowry, 1996). The presence of the shade from trees helps to cool the surrounding air hence slowing down the rate of evaporation. As mentioned in Section 5.5.3, the cooler and more moist air in hot-dry climates represents increased human comfort (ibid).

6.1.5 Summary of the Investigation of “Shade”

Based on the above evidence, it was surmised that shade was highly probable in the original Arabic configuration of the Court of the Lions. Not only would shade help to protect the marble from deterioration, shade also indicates a reduction in solar radiation and cool the building. Ultimately, the use of shade in a courtyard would increase the human comfort in a hot and dry climate by using the evaporative cooling effect of shade from trees, moisture from water features, and evapotranspiration of plants.
6.2 THE INVESTIGATION OF “TREE FORM AND ARRANGEMENTS”

6.2.1 Defining Location, Date and Time Setting for Computer Simulations

**Location setting:** In order to simulate the shade conditions accurately, the virtual location of all computer models (*Section 4.3, 4.4 and 4.6*) was set to Latitude: 37°10'37.73" N and Longitude: 3°35'21.3" W which is the geographic coordinate of Court of the Lions according to Google Earth.

**Date and Time setting:** The chosen date and time for computer simulation was June 21\(^{st}\), the Summer Solstice. It is the sun’s position at its highest point in the sky for the entire year. All objects would cast their absolute shortest shadows of the year. By knowing the height of the building facade and the sun’s angle of the Summer Solstice at a geographic location, it was then possible to find out the minimum height of a tree that can cast a shadow long enough to provide adequate shade.

![Figure 53: Concept diagram for determining minimum height of tree to shade building facade](image)

Figure 53: Concept diagram for determining minimum height of tree to shade building facade
enough to shade and to protect the entire height of building facade (Figure 53) from solar radiation. The figure also shows that the tree height required to cast shade would depend on its relative distance away from the building. The further the tree is from the building, the taller the tree is needed to cast shade on the building facade.

6.2.2 The Creation of “Rules of Trees”

The “Rules of Trees” were the test parameters for visual analysis used within computer simulations. These “rules” were formulated on a summary of information collected from Literature Review (Chapter 5) related to trees. As well, these rules acted as simulation guidelines for tree arrangements within the Court of the Lions and should not be violated. These rules were stated as follows:

**T1: Canopy of trees cannot interfere with the surrounding architecture in terms of sight lines**

This rule was derived from the following points:

- “No matter how much the trees and plants grew, they never interfered with the architecture around them” (Ali, 1999, p. 105), refer to Section 5.2.2.3.

- Height of the planting prevented interference with the architecture (Irwin, 2004; Van Zuylen, 1999), refer to Section 5.3.4.9.

**T2: Clear view from 2nd storey chamber to see the Courtyard below**

This rule was derived from the following point:

- Second-storey chambers look down into the courtyard (Dickie, 1992; Ruggles, 2000), refer to Section 5.3.4.10.
**T3: Location of trees should be on grid points which lines up with the columns**

This rule was derived from the following points:

- The placement of trees normally lined up with the columns of the building to emphasize this "extension" visual effect, refer to Section 5.2.2.3.

- Based on the above point, a grid was produced by lining up the column locations in the east-west and north-south directions within Court of the Lions. The grid points, shown as black dots, became the possible locations for trees and would align the trees “automatically” with the columns in all four directions (Figure 54).

![Figure 54: Grid establishment for placement of trees](image)

### 6.2.3 The General Process of the Computer Simulations for Trees

The purpose of the simulations was to define the appropriate tree form, height and arrangement to generate the necessary shade that satisfies the following objectives:

- To generate shade to minimize the exposure of marble columns and fountain as well as water evaporation to the sun in summer
- To generate shade along the north facade of the Court of the Lions to absorb solar radiation for the purpose of lowering heat gain to the building.

**Types of computer model for simulations:** Two types of models were used: concept model (Section 4.3) and illumination model (Section 4.4).

**Tree form for simulations:** Two tree forms were used for the simulations: deciduous and palm. Both types were widely used for shading.

### 6.2.4 The Tree Simulation Process

![Concept Map for Tree Simulations](image)

**Figure 55:** Concept Map for Tree Simulations
The concept map shown above (Figure 55) summarized the entire simulation process of trees. The following outlined the generic steps involved for the simulation of deciduous and palm tree form. Steps 1 to 3 below were performed using the concept model and Step 4 using the illumination model. Deciduous tree form, height and arrangements were simulated first (Section 6.2.4.1 below). Palm trees were then modelled by repeating the exact process as deciduous trees (Section 6.2.4.2).

6.2.4.1 Deciduous tree simulation procedure

**Step 1: Test for tree location, height and corresponding shade**

**Procedure:** A typical deciduous tree form was placed in the North East quadrant of the Court of the Lions with respect to Rules of Tree T3, which implied that the position of tree trunk could only be placed on the predefined grid points in order to line up with the columns (Figure 56). The tree was placed on different grid points and resized to different heights by iterations trying to determine its optimum location, height, as well as the corresponding shade of the tree canopy using the predetermined Date, Time and Location Setting in Section 6.2.1 for the sun’s angle. This action of iteration was continued until the tree height with its relative canopy size could generate considerable shade to cover the height of the northern facade of the Courtyard under its own shadow. The generated shade would also protect the columns located on the lower portion of the same north facade. Care was taken to ensure the canopy of the tree would not penetrate into the perforated screens or touch other parts of building. In reality, such
penetration would mean severe damage to the delicate structure of the plaster artwork.

Figure 56: The possible tree positions (black circles) in NE quadrant

**Results from deciduous tree form:** The optimum locations for the deciduous tree were found to be along Row 2 running along an east-west direction on the grid point (see Figure 56 and Figure 57). When the deciduous tree was placed on a grid point along Row 2, it was found that when the sun is at its zenith on June 21, it would require a deciduous tree with a minimum height of 40 feet (12.2m) tall to shade the north facade of the promenade (Figure 57). This tree height would have a corresponding tree canopy diameter of 25 feet (7.6m). This was also the maximum diameter of canopy that the tree could “fit” at that location without touching the facade of the arcade.
Figure 57: Deciduous tree form simulation (40 feet high)

Row 1 was too close to the arcade. This alignment could only accommodate small trees that cannot shade the entire height of the northern facade. Row 3 is too far away and would require extremely large tree to create the same shading purpose. As well the canopy of this extremely large tree would create too much physical interfere with the tree symmetrically planted on the South-East quadrant according to Islamic garden principle. Furthermore Row 2 almost runs along the middle in the East-West directions, satisfying the idea of symmetrical planting.

**Step 2: Test for tree arrangement**

**Procedure:** Trees with the same dimensions define in Step 1 were arranged within the Courtyard based on the position possibilities of the available grid points respecting Rules of Tree T3. Trees were arranged in different
iterations until they could be symmetrically arranged amongst the four quadrants of the planting beds.

**Results from deciduous tree arrangement:** An arrangement of eight trees was geometrically arranged in the Courtyard, two in each quadrant (Figure 58). Each tree simulated was 40 feet high with 25 feet canopy diameter. Tree canopy in each quadrant slightly overlapped each other. All canopies did not interfere with the facade of the arcade on all four sides.

![Figure 58: Plan view of deciduous tree arrangement](image)

**Step 3: Validation of tree form and arrangement**

**Procedure:** This step was crucial in validating and eliminating any tree arrangements that did not satisfy the Rules of Trees T1 and T2. Views were simulated on ground level as well as from the 2\(^{nd}\) storey chamber. As a result of this validation step, the computer calculation time for the illumination simulation (Step 4) was drastically cut down by only focusing on the calculation of the “successful candidate” tree forms and arrangements that can pass T1 and T2.
Any tree form and arrangement that did not satisfy T1 and T2 would not proceed to step 4.

**Results from deciduous tree form and arrangement:** This tree arrangement violated both of the Rules of Trees T1 and T2 with the canopy of the trees visually blocking major portions of the facades of the highly decorative surrounding arcades (Figure 59 and Figure 60). The view to the Courtyard was completely blocked from 2nd Storey Chamber (Figure 61) because of the deciduous tree canopy. The eight trees produced full and dense shade in the Courtyard. It is possible to get an idea of the dense shade and visual interference with architecture in reality by looking at site photos of the orange trees in the Court of Mexuar (Figure 62 and Figure 63), then try to imagine the same effects for a much larger tree (40 feet in height).

![Figure 59: Simulated view of deciduous tree arrangement viewed from ground level from West Pavilion looking East (Sitting Position)](image-url)
Figure 60: Simulated view South-East looking North-West (Standing Position)

Figure 61: Simulated view of deciduous tree arrangement viewed from 2nd Storey Shamber looking North
Figure 62: Deciduous (orange) trees in Court of Mexuar, within Alhambra, showing visual interference with building facade

Figure 63: Close up of two orange trees showing dense shade below and visual interference with arcade
In summary, it can be seen that all three images (Figure 59 to Figure 61) showed heavy visual interference with architecture. Hence deciduous tree type was not suitable to be used in Court of the Lions. The tree type failed to satisfy the Rules of Trees T1 and T2 and did not advance to Step 4 for illumination simulation.

6.2.4.2 Palm tree simulation procedure

The exact tree simulation process outlined in Section 6.2.4.1 for the deciduous tree simulation procedure was repeated for palm trees. The results are shown below:

Step 1: Test for tree location, height and corresponding shade

Results from palm tree form: Because of the relatively smaller canopy size of the palm tree when compared to the canopy of deciduous tree of the same height at 40 feet, the deciduous tree was replaced by four palm trees in order to generate a similar canopy size with similar corresponding shade coverage when compared with the deciduous tree (Figure 64 and Figure 65).

Figure 64: Tree configuration between palm (left) and deciduous (right) tree form
Note: Dotted circle indicates the size of deciduous tree canopy
Step 2: Test for tree arrangement

Result from palm tree arrangement: The eight deciduous trees were replaced by 32 palm trees (Figure 66) in a similar configuration as shown in...
Figure 65, eight palm trees per quadrant. The 32 palm trees created partial shade in the courtyard with interesting shadow pattern on the ground (Figure 69).

**Step 3: Validation of tree form and arrangement**

**Validation of palm tree form and arrangement:** The palm tree form allowed all the building facades to remain visible (Figure 67 and Figure 68) which satisfied Tree Rule T1 (Canopy cannot interfere with architecture visually). The Courtyard was also completely visible from the 2\textsuperscript{nd} Storey Chamber (Figure 69) because the canopy of palm trees was positioned well above the upper part of the facades. Hence Tree Rule T2 was also satisfied. The arrangement of the 32 palm trees produced an interesting shading pattern on the ground as well as a partial shade environment. In reality the shade from palm leaves is much finer and more diffused (Figure 70). The palm tree with its arrangement was advanced to the Step 4, illumination simulation.

![Figure 67: Simulated view of palm tree arrangement viewed from ground level from West Pavilion looking East (Sitting Position)](image)
Figure 68: Simulated view from South-East looking North-West (Standing Position)

Figure 69: Simulated view of palm tree arrangement viewed from 2nd Storey Chamber looking North
Step 4: Illumination simulation – “with palm tree” version

Procedure: The 32 palm trees were imported together with the Concept Model of the Court of the Lions into Lightscape 3.2 for illumination simulation. After the global illumination calculation process, the calculated result of the light energy information was displayed using the lighting analysis function and saved as a computer image.

In order to see how effective the trees helped in light energy reduction along the north facade and on marble surfaces, a separate “no tree” version of the illumination simulation was created. The “no tree” version was created in the same model environment but with the 32 palm trees “layer” turned off. After the global illumination calculation process, the result of the light energy information was saved as another computer image.
Since the views were identical between the “with tree” and “no tree” simulation versions, the colour of the same surface of the facade between the two images would indicate the difference in the lighting energy received. By comparing the two images visually side by side, it was possible to “see” how much less lighting energy was deposited on the model surfaces on the “with trees” image due to the presence of the 32 palm trees in the Court of the Lions.

**Result from the “no trees” version:** The image (Figure 71) showed the light energy received on the north facade of the promenade was very high when compared to the other three sides of the promenade. Furthermore this image of the “no tree” version seemed to correspond to the diagram in Section 5.4.1.2 which showed the level of individual column damage within the Courtyard where the columns on the north facade are effected most severely.

**Result from the “with tree” version:** The image (Figure 72) showed a uniform illumination across all facades and partial shaded courtyard. This simulation showed the installation of palm trees would have drastically reduced the received sun’s energy on the facade of the north arcade when compared to the illumination simulation with no trees (Figure 71). The image also showed the light energy received on the marble column was less than the “no tree” version. This suggests that the temperature extreme on the marble surfaces would be less as would its deterioration. It also echoes the *Quranic* description mentioned earlier (Section 5.6.2.2 and 5.6.2.3) --- no extreme heat from the sun or bitter cold (*Quran* 35:20-21; 76:13).
Figure 71: Light energy deposition on the model - "no tree" version

Figure 72: Light energy deposited on the model – “with tree” version
6.3 THE INVESTIGATION OF “SHRUB TYPES AND ARRANGEMENTS”

6.3.1 The Creation of “Rules of Shrubs”

Similar to the “Rules of Trees” in Section 6.2.2, the “Rules of Shrubs” were created as test parameters for the computer simulations. Again, these “rules” were formulated on a summary of information collected from the Literature Review (Chapter 5) related to shrubs. These rules were stated as follows:

S1: **At a seated position at floor level, the height of shrubs cannot obstruct the view of the fountain.**

This rule was derived from the following points:

- The sunken vegetation and embedded water basins were intended for viewers seated on carpets or low cushions at walkway level (Ruggles, 2000), refer to Section 5.3.4.9

- The carpet of flowers would not impede the view of the fountain (Irwin, 2004), refer to Section 5.3.4.9

S2: **At a seated position at floor level, the height of shrubs needed to be high enough to hide the footing of columns.**

This rule was derived from the following points:

- The sunken vegetation and embedded water basins were intended for viewers seated on carpet or low cushions at floor level (Ruggles, 2000), refer to Section 5.3.4.9

- the garden plants in the middle prevented viewers from seeing how the pillars rested on their marble bases (Cid et al., 1994), refer to Section 5.3.4.1

S3: **Shrubs for the “carpet effect” should be scented and with colour**

This rule was derived from the following point:
• perfumed floral carpet (Van Zuylen, 1999), refer to Section 5.3.4.9
• all plants in Paradise have fragrant aromas, refer to Section 5.6.1.1
• plants in Paradise provide colour (Nassar, 2002), refer to Section 5.6.1

S4: Fruits trees should be planted next to the pavilions

This rule was derived from the following points:

• fruits in Paradise are easy to reach, refer to Section 5.6.1.2
• plants in Paradise provide food (Nassar, 2002), refer to Section 5.6.1

This rule was also based on the following personal assumption:

The pavilions, being described as the most delicate expressions of the Nasrid interior (Bermudez Lopez & Galera Andreu, 1999) in Section 5.3.6.6, were created for a significant purpose in the Court of the Lions. The beauty of these pavilions could be related to the descriptions of the pavilions in Paradise. For example, pavilions are made of precious jewels described in Hadith (Yakup, 2005). Based on the heavenly descriptions about pavilions in Paradise, the two pavilions in Court of the Lions could be the prime locations for the Sultan earthly appreciation. He would sit and look around, appreciating the delicate details of the pavilion together with the beauty of the garden surrounding him. Based on this assumption, fruit trees should be planted next to the pavilions so that the fruits would be within the reach of the Sultan echoing the description from the Holy Quran where it says “fruits are easy to reach” mentioned in Section 5.6.1.2.
6.3.2 The General Process of the Computer Simulations for Shrubs

The purpose of the simulation was to:

- To determine the appropriate size of shrubs for the “carpet effect” which could satisfy Shrub Rules S1 and S2 above.
- To determine the specific locations of fruit trees according to Shrub Rule S4.

It is worth noting that the shrubs in reality also need to tolerate the partial shade condition created by the canopy of the palm trees (Step 3 in Section 6.2.4.2).

6.3.3 The Shrub Simulation Process

Figure 73: Concept Map for Shrub Simulation
The concept map shown above (see Figure 73) summarized the entire simulation process of shrubs. The following outlined the steps involved for the simulation of shrubs. All steps were performed using the concept model.

**Step 1: Test shrub height for “carpet effect”**

*Procedure:* Four boxes were created within the Concept Model of Court of the Lions with dimensions similar to the widths and lengths of the four planting beds. These boxes were for the height simulation of the shrubs for the “carpet effect”. A simulated view point was set to be in a sitting position under the West Pavilion looking east (see Figure 74). The height of the four boxes was then adjusted by iterations until the Rules of Shrubs S1 and S2 were satisfied. The following are the visual feedback of the three simulated shrub height: 3 feet or 91.4cm (Figure 74), 4 feet or 121.9cm (Figure 75), and 4.5 feet or 137.1cm (Figure 76).

![Image](image.png)

**Figure 74:** Shrub “carpet effect” simulation - shrub height 3 ft (91.4cm)
Results: These three computer simulations show that in order to satisfy both Rules of Shrubs S1 and S2 at a sitting position, the shrub height needed to be between 4 ft (121.9cm) to 4.5 ft (137.1cm). The optimal height level should be 4 ft (121.9cm) and allows an additional 6 inches (15.2cm) to accommodate the natural shrub height variation. With the shrub height of 4 ft (121.9cm) growing from the 3 ft (91.4cm) sunken planting bed, the effective height of the “carpet effect” would be 1 ft (30.5cm) high above the walkway as shown in Figure 75.
Step 2: Test location and size of fruit trees next to the Pavilions

Procedure: A small tree in deciduous tree form of 8 feet in height was placed in the Concept Model representing the height of an orange tree. The tree was placed immediately north of the East Pavilion in the North East quadrant of the planting bed. Care was taken to ensure the orange tree was not in contact with the any building elements. Two orange trees could fit comfortably side by side along the East end of the planting bed. Two more trees were symmetrically placed in a similar manner on the south side of the East Pavilion. The same planting concept for the orange trees was employed for the East Pavilion (Figure 77).

Figure 77: Orange trees planted on both sides of the East Pavilion
Note: Palm trees are not shown in the above image for illustration purpose

Results: From the orange tree simulation, it was found that the height of 8 ft. tall orange tree would not create any major visual interference when a person sits under the pavilion and view towards the fountain at the centre of the Courtyard
(Figure 78). Minor visual interference does occur when viewed towards the two sides of the pavilion (Figure 79), but not to the extent of covering the facade of the arcade. With this planting arrangement, the canopy top would be the same height as a 5 ft. (152.4cm) high person in standing position (see black figure in Figure 77). It is because the 8 ft. (243.8cm) high tree would be planted 3 ft. (91.4cm) below. This height is a favourable height position for fruit plucking in both sitting and standing positions as the fruits would be directly in front of the person. Both the location of the orange tree and the canopy height satisfied Rules of Shrub S4 (Figure 77).

Figure 78: View at entrance of the West Pavilion looking East (Sitting Position)

Figure 79: View of shrubs left and right of pavilion (Sitting Position)
7.1 FROM QUEST OF KNOWLEDGE TO DISCOVERY

The quest for knowledge about the garden atmosphere of the Court of the Lions was started by harnessing information from different professions, languages and time. Each piece of information in the Literature Review chapter is like a piece of a jigsaw puzzle. Although the individual pieces of puzzle only show very limited content, joining them together logically helped to see a larger portion of the puzzle that represent the lost garden history of Court of the Lions. Piecing the collected content together from the Literature Review helped to build up the foundation knowledge related to the Court of the Lions and helped to define the known elements. The search also identified the possibility of three missing pieces of puzzle which would play a critical role in defining the garden atmosphere of the Court of the Lions. These three missing pieces were the missing variables under the investigation of this study.

Two of the three missing variables, namely the “tree” and “shrub” related variables, were heavily dependent on the visual feedback from computer simulations and were used transparently as virtual test instruments in the research process. Without the concept model simulations, it would not be possible to have real-time feedback of the shadow information with simultaneous design manipulations on trees size, location, arrangements and view points. Through personal experience in landscape architecture and multimedia design, this spontaneous reaction loop of mouse-eye-mind action helped tremendously in finding solutions for the “tree” and “shrub” related variables. At any moment in
time, the simulation outcome could change within a second due to the simultaneous engagement of moving the mouse, getting real-time visual feedback from the model and making the split second decision of the “what if” which affects the next minute directional movement of the mouse. As well, without the concept model, it would not be easy to ascertain the visual interference caused by the placement of the deciduous tree form for shading within the Courtyard.

Without the illumination model simulation, it would not be possible to “see” the light energy difference between the “with trees” and the “no trees” version. The pseudo-colour from the images of the two versions helped to confirm how much less light energy could be deposited along the northern facade and on sunny side of the columns due to the presence of palm trees. As a result of the trees, the arcade would be shaded and cooler. The shade from trees also helped to minimize or to lower the temperature extreme which was identified by other researchers as one of the main contributors for the initiation of marble deterioration.

Without photorealistic model simulation using computer images and animations, design effects such as the graceful movement of shade from the palm leaves projected on the original polychromed facade of the arcade could

Figure 80: Computer animation study of movement of palm leaves and shade
not be visualized (Figure 80). Most importantly it would not be possible to visually experience the overall beauty of the garden atmosphere of the Court of the Lions back in 1391 without the spontaneous emotional response when viewing these photorealistic computer images and animations.

    In essence, it was the strong support of computer simulation technology, which was being applied transparently, with the sound research logic which helped to provide convincing evidence and results for this study.

7.2 THE INTEGRATION OF ELEMENTS

As mentioned in Section 2.4.1, an Islamic garden is the integration of architectural and landscape elements through complement and/or contrast amongst design elements for creating design interest. The following shows the integration of all the elements as described in Section 3.2 --- known and missing elements, both landscape and architectural (Figure 81).
The two figures below (Figure 82 and Figure 83) help to describe the contribution of the missing elements found in this study and they helped to demonstrate a much closer relationship between architecture and landscape elements. As well, these missing elements (black ovals) added new vocabulary and new definitions to the existing descriptions (white ovals) of the Court of the Lions, creating a much richer garden atmosphere than without them.
Figure 82: Integration through complementary between elements
Figure 83: Integration by contrast of elements

7.3 THE GARDEN ATMOSPHERE IN 1391

The following is a reconstruction of the possible sequence of events as Sultan Mohammad V would have experienced within the Court of the Lions in the year 1391. Photorealistic computer images are randomly placed throughout the paragraphs to give addition visual information to the text description:

After a long morning session of administrative work, the Sultan took his normal noon break. Escort by four of his bodyguards, he walked slowly and
chatted with his chief administrator who tried to finalize the Sultan’s busy late afternoon schedule prior to reaching the entrance of the Palace of the Lions. While they were all standing at the gateway of the Palace, waiting for the final words between the Sultan and his chief administrator, everyone appreciated the beautiful scent coming from the Court of the Lions through the gateway. After receiving the Salam (the peace greeting) from his administrator, the Sultan entered the Palace alone. As he walked along the dimly lit corridor, he could hear the murmuring sound of water coming from the garden. He was immediately greeted by two of his servants at the other end of the corridor as he entered the Court of the Lions. One of them departed quickly with excitement to inform the Sultan’s family members about his arrival, while the other walked behind the Sultan as he moved slowly towards the Hall of the Two Sisters. Strolling along the arcade on the way to the Hall, he felt the cooled air reaching his face as if Mother Nature was sending him the “cool” greetings to welcome him home on the hot and dry summer day. In fact the cooled air was prepared by his servants since early morning using the Evaporative Cooling Strategy. During his journey to the Hall, he could not keep his eyes from the attraction of the garden with the unpredictable shadow pattern from the palm trees. Not only the 124 slender
marble columns, which surrounded the Courtyard, disguise the distinction between interior and exterior space, the small diameter of the 32 palm tree trunks visually blended with the columns naturally providing an interpenetrating effect. One cannot tell the start and end of the architecture and the landscape. The two visually fused together to become one continuous space. The Fountain of the Lions seemed to be playing hide-and-seek with the Sultan, appearing and disappearing amongst the columns and tree trunks while he was walking.

As the Sultan's walked into the Hall of the Two Sisters, he took a quick glance at the highly decorative ceiling that the Hall was famous for and continued walking towards the other end of the Hall to the Lindaraja Mirador. He sat there momentarily and looked towards the distant mountains of Albaicin and the unobstructed panoramic view of Granada. He closed his eyes and took a few relaxing deep breaths when he heard the foot steps from his servant approaching him and informed him that lunch was being served in the West Pavilion.

Before arriving at the Pavilion, he was greeted by his family members and together they walked towards the Pavilion. The food and drinks were already arranged nicely around the small bubbling fountain located at the center of the Pavilion with cushions and carpets already decorating the four
corners of this Pavilion. After enjoying the lunch, with the Sultan’s permission, the family members gracefully departed the Pavilion by greeting him Salam. This allowed the Sultan some private and quiet moments where he could temporarily disassociate himself from all earthly business and fully relax himself through the five senses.

The Sultan leaned back on a corner against the comfortable cushions and started looking around the Courtyard which was solely built for his enjoyment and endless appreciation. While drinking his cup of Arab tea, he realized the nice scent of his tea was being mixed with the pleasant aroma from the flowering shrubs, carried around the Courtyard by the breeze. The flowering shrubs provided the floral carpet effect around the Pavilion as if the floral carpet was an extension of the carpet that the Sultan was sitting on. The natural floral carpet beauty created a good contrast against the vertical and manmade
multi-coloured facades of the arcade. The polychromed facade appearance made the architecture looked like fabric hanging down from Heaven.

The same breeze that carried the scent from flowering shrubs also made the palm trees slightly sway in the air. The organic lines and softness of the palm tree trunks made sharp contrast against the rigid and static appearance of marble columns. Not only the Sultan could see the trees and the columns complemented each other in terms of rhythm and spacing, there existed other interesting complementary and contrasting expressions between them for his visual exploration. For example, the abstracted decorations on the columns which complemented the appearance of the palm tree trunks; the contrast between the three-dimensional form of palm trees and two-dimensional profile shape of palm trees using columns and arches; as well as the complex mass-void relationships between “tree canopy with tree trunks” and “arcade roof with columns” which complements each other.

After pondering these intricate relationships between the palm trees and columns for a while, the Sultan switched his focus to look at the water and shade effects --- the two most essential design elements in his Islamic garden. Both movement of water and the shadow from the leaves of the palm trees added
dynamics to the overall appearance of the Courtyard. He was dazzled by the shadow effects from the palm leaves dancing on the polychromed surface of the arcade. The randomness of the movement of the shadow was simply graceful, unpredictable and very pleasing to look at. At certain instances, the shadow seemed to be dancing according to the constant soothing background sound effect of water with the songs from birds.

A gush of wind created a rattling sound of the leaves from the nearby orange trees. This broke the Sultan’s attention away from the water and shade. He extended his arm and reached out for an orange, but realized that the fruit was not ripe yet. So instead of plucking it, he sent his servant to bring him some freshly cut fruits and asked his family to join him for the refreshment before heading back to work for the late afternoon session.

The Court of the Lions was definitely Sultan Mohammad V’s earthly paradise. As well,
the Courtyard was the place where he enjoyed solitude with details of every
design element geared for his enjoyment. The Courtyard provided him a spiritual
imagery of his anticipation of entering the unimaginably beautiful Paradise in
Heaven after Judgment Day as described according to the *Holy Quran*. The deep
spiritual thoughts and the anticipation became his driving force in reality, which
also acted as a physical reminder for the Sultan, to continue exercising his good
deeds to his all of his people.

7.4 IMPLICATIONS FOR LANDSCAPE ARCHITECTURE

7.4.1 Raising Awareness

This research is possibly the first comprehensive investigation of the Court of
the Lions from a landscape architecture perspective. Although the Courtyard has
been known for its historic significance, it has been surprising to know how
little was written about the Courtyard within the field of landscape architecture. To
overcome the paucity of information, the majority of the research materials were
collected from other professional disciplines across different historic periods and
languages. The importance of the data “brought back” from other disciplines
proved to be invaluable background information for this research. As well, the
collected data helps to build a landscape architectural perspective of the Court of
the Lions and could benefit future research in this area.

Furthermore, by reading through this study, it is hoped that the viewers
would come to realize the underlying importance of this kind of research --- one
should actively question the information presented on any historic sites and not
simply believe in the contemporary conditions and descriptions without critically analyzing them. It is hoped that this study of the Court of the Lions can serve as an example where the effort of critically analyzing and actively questioning the contemporary images and descriptions of the Courtyard initiated this research. Subsequently the quest for detailed information of the Court of the Lions gives substance to a lingering suspicion that this famed courtyard is far more complex than its current oversimplified graveled representation.

7.4.2 Innovative Use of Computer 3D Technology in the Research Process

Computer 3D models were used throughout the research process as virtual test instruments as well as for the final presentation of the research findings. The innovative use of 3D technology helped to analyze data, test design concept and present research information through a series of computer simulations. The research findings would not be possible without the use of computer 3D modeling and visualization technologies.

7.4.3 A New Benchmark in Computer Visualization

According to the researcher’s findings within the research period, this was the first time in history a virtual Court of the Lions computer model was reconstructed with an attempt to reveal the long disappeared original colours on the architectural elements within the Courtyard. Photorealistic computer images and animations helped viewers to experience the richness of the Courtyard surroundings which contribute to the overall garden atmosphere of this famous Courtyard.
7.5 FUTURE RESEARCH

This study described the discovery process of three missing and essential elements for recreating the garden atmosphere of the Court of the Lions. With the rediscovery of these missing elements, this study marks the beginning of endless opportunities for future research related to this topic of research. Only a few ideas are described below:

1. **In depth research of plant materials**: This will be considered as the next logical step. Although the photorealistic computer simulation showed plant materials such as shrubs and palm trees, they were only correct to their appropriate size for the purpose of visual simulation of the garden atmosphere. Further study of the use of shrubs in terms of the species as well as, in particular, the selection of palm trees species will be highly beneficial.

2. **More computer simulations of palm trees**: The selection of particular palm tree species may contribute to different tree forms in terms of height and canopy size. These factors may, or may not, in turn affect the corresponding shade pattern in the Courtyard. Hence a complete set of computer models with the presence of different types of palm trees would be needed.

3. **Better architectural details**: As described in Chapter Four, the intention was to create a virtual replica of the Court of the Lions for simulation purposes. However the detailed architectural information has been severely limited. The current model could only be described as
proportionally correct, but far from the idea as “virtual replica” from the researcher’s original plan. Recovery of detailed architectural drawings would further increase the accuracy of the computer simulations.

4. **Use different research approach:** Since the research approach was original to this study using Grounded Theory, the evaluation of the findings could not be justified or based on other research because of no precedents. As well, the findings and analysis in this research could be considered as subjective based on the researcher. It is only through repetition of similar studies using different research approaches and criteria that would complement, or disagree with, the findings of this research. Hence similar research is highly recommended.

7.6 **AUTHOR’S DISCUSSION**

Through the process of this research, I have become increasingly aware of my opinions and how they conflict and coincide with the others. This realization came from the famous "orange trees" description from the European visitors who visited the Court of the Lions (see Table 1). Not a single visitor mentioned that they saw palm trees, but only orange trees or paved marble floor. As well, no artistic illustrations had the presence of palm trees in them.

Another realization of conflict came from a discussion during the conference in Spain. Many identifiable conference presenters and professionals such as architects, environmental scientists and university professors were complimentary on the clear research logic and accepted the findings of this
research. However two conference participants voiced out in Spanish immediately after my conference presentation regarding their disagreement on the idea of palm trees and kept mentioning the idea of orange trees. While I managed to defend my research findings, two days later I was approached by another Spanish conference participant during a social event in the town centre of Baeza. He pointed at a group of orange trees planted along a street outside a church and talked in length. Through translation, he mentioned that the local Spanish people were told and have “believed in” the presence of orange trees within the Court of the Lions for generations. However he said after having deep thoughts for two days, he started to see the logic and accepted the idea of palm trees. From this conversation, I came to realize that I have accidentally uprooted their cultural “beliefs” in orange trees and replanted the new idea of palm trees in their mind which was hard for them to accept.

Out of all the information collected for this research, there was only one piece of evidence that coincide with my research findings. It was a rough hand sketch shown in Prieto-Moreno’s book in 1963 (Prieto-Moreno, 1962; Prieto-Moreno, 1963) which illustrated the palm trees planted within the Court of the Lions (see Figure 84). Unfortunately the sketch was not related to any text in the book. Both English and French versions of his book had titles under the illustration but did not suggest any significant evidence to tell how or where the palm tree idea came from. Furthermore how did Prieto-Moreno “know” the existence of palm tree in Court of the Lions when no archaeological digging had ever been performed within the Courtyard? If this was his original idea, where did
his idea come from? These questions remain unanswered. Prieto-Moreno’s sketch seemed to be a coincidence on the idea of palm trees rather than a piece of evidence that could be used to support this research.

Figure 84: Sketch of palm forest within Court of the Lions by Prieto-Moreno

_Croquis qui explique la conception toute naturelle de la Cour des Lions_
_(translation: Sketch which explains the very natural design of the Court of the Lions)_
8.1 RESEARCH GOAL AND OBJECTIVES REVISITED

As described in the Introduction Chapter, the goal of this research was to test and propose the original garden atmosphere of the Court of the Lions as it was in 1391. In order to achieve the goal of this research, four objectives were identified. Each of these has been accomplished.

First, it was essential to search and to analyze evidence of any potentially missing landscape elements within the Court of the Lions. This objective was achieved started by reviewing a number of primary sources which provided the foundation information for the framework and supported the remainder of the research. The collected information was rearranged with the utilization of grounded theory and concept mapping and eventually a pattern started to emerge. This pattern led to the discovery of the “shade” variable. With the possibility of shade identified, two dependent and closely-related variables, which were seen to structure the garden, were then identified, namely: tree form and arrangements, and shrub types and arrangements. These were the three missing variables under the investigation of this study.

Second, computer 3D models and simulations were used as virtual test instruments which helped to test the feasibilities of the last two variables. The concept model helped to provide valuable visual feedback for defining the possible form, size, arrangement of the trees and shrubs. The illumination model helped to “see” the employment benefits of using palm trees within the Court of the Lions for solar protection of the building arcade and the marble.
Third, the missing variables were integrated well with the known variables to redefine the possible garden atmosphere of the Court of the Lions as it was in 1391. The vanished elements of shade, trees and shrubs were reunited seamlessly with the existing elements of the Court of the Lions. The new descriptive vocabulary from the vanished elements helped compliment the beautifully described expressions of the Court of the Lions. Together, the merged description further enhanced the relationship between architecture and landscape elements.

Fourth, the research findings of this final objective was interpreted successfully using photorealistic computer images and animations, with the object of re-enacting the atmosphere of the original garden and surrounding structure created during the 2nd reign of Sultan Mohammad V in 1391.

8.2 CONCLUDING REMARKS

This research was conceived in the quest for the missing elements of shade, trees and shrubs. Throughout the study of these elements it was hard not to be inspired by the imagined shadowing from lightly swaying leaves of overhead palm trees, the sounds of water issuing from the central fountain, the reflected light on the polychromatic facades of the promenades, the scented and colourful shrubs as well as the taste of oranges plucked from nearby orange trees. The light was the ultimate element which provided the “magic” in blending all intricate design elements together to become one unified piece of living art.
This was the luxuriant garden atmosphere that Sultan Mohammad V would have experienced and enjoyed in the year 1391.

The long rule of the Sultan brought the ultimate flowering of Nasrid art, architecture and decorative arts (Van Zuylen, 1999). He built the courtyard for his pleasure, a space which also revealed the vividness of his life and times with an underlying message of peace. He was known for his preference for diplomatic negotiations rather than war (Fernandez-Puertas, 1997b). His tolerance and trust of other religions went as far as to include Christians as part of his personal guard (ibid). He protected three hundred Jewish families from being slaughtered and welcomed them into his emirate to continue practicing their own occupations (ibid). It was this societal unity and stability that allowed him to focus on building prosperity for his people during his reign. It was also this peace which provided him the personal freedom and creative opportunities to build an engineering and architectural marvel with the beauty of a vanished garden situated within the Alhambra Palace. The Court of the Lions was the gem he realized, a paradise garden for aesthetic and religious repose. Today the Courtyard sits at odds to that historic place and this research presents a way to piece together what could have been and what still could be.


