A Conceptual Model for Climatic-responsive Vernacular Architectural Forms

Solmaz Kamalifard[1] and Arya Assadi-Langroudi[2]

[1] Institute for Art and Architecture, Academy of Fine Arts Vienna,
solmaz.kamalifard@student.akbild.ac.at
[2] Department of Computing and Engineering, University of East London.

Abstract: Indoor lighting, in terms of its spatial coverage, spectral range and extent is closely associated with occupants' behaviour, yet little is known about its links with now-abandoned 19th century vernacular architectural forms of dry-and-arid climates in central Asia. Sustainable use of energy for domestic purposes is a critical component of the resilience of urban systems to urban sprawl (and escalating energy demands), mineral resource shortage and changing climate. Domestic energy use is a function of occupants' behaviour in adjusting themselves to space through movement, which is driven by interrelated light-space-time. A better understanding of such interactions, in the context of energy efficient Iranian vernacular architecture can allow the adoption of traditional styles in design of contemporary indoor living spaces, thereby indirectly influencing occupants' lifestyles towards lesser use of artificial lighting and energy conservation. It is in trying to understand how vernacular style can be turned into purposeful action that each core domain of vernacular architecture, and the dynamic of light and human through them, should be determined and brought to bear. In doing so, we present a conceptual model, built through field observations - of five three historical buildings in Kashan, Central Iran - interview and archival studies. The model informs on how occupant's perception of space and response varies with time, space configuration and lighting levels.

Keywords: Daylight, Human, Interior Space, Vernacular, Perception, Energy, Behaviour

1. Introduction

The global urban sprawl, rapid industrialisation, growing reliance on energy delivered mainly through fossil fuels and modern-day consumption habits continues to strain our energy resources. Unwelcomed environmental impacts of unsustainable exploitation of earth reserves (in form of emissions and extreme climates) and the interlinked uncertain security of supply necessitates policy-makers to work towards balancing the supply and demand in at domestic levels. Domestic energy use is a function of occupants' behaviour in adjusting themselves to space through movement, which is driven by interplay among light, space, and time. A better understanding of such interactions, in the context of energy efficient Iranian vernacular architecture can allow the adoption of traditional styles in design of contemporary indoor living spaces, thereby indirectly influencing occupants' lifestyles towards lesser use of artificial lighting and energy conservation.

People are not inert recipients of the environment; they interact with environment in an effort to optimize their living conditions (Humphreys, 1995). Environmental conditions affect human's activities, physical and mental state (Leaman and Bordass, 2000). Light, a key environmental element, has a pivotal effect on human's perception of space. Light transforms the spatial context and facilitates the establishment of relationships between occupants and their surroundings. Light is connected to time, and has, intrinsically, the features of movement, sequence, and variation in every moment. The role of natural light in human-environment interaction has been the subject of much debate and once fully established can enable an integrated systems approach to the multi-functional provisions of the environment to be adopted for future homes (Fitch, 1972) and will offer a chance to restore the degraded symbiosis between the nature and the built environment.

This paper investigates light and shadow and their implications on architectural design and occupant's behaviour through an interpretive, archival, and field study. This contribution will revisit the early Persian architectural designs for dwellings and investigate occupant's interaction with environment in semi-arid climates, that is generally sunny and dry year-round. With the main emphasis on the vernacular residential buildings dated back to the 19th century, where natural light was principally exploited as the main source of energy, this paper provides a new understanding of the behaviour of occupants and their daily activities adjusted to timed movement of sunlight. It explores vernacular architecture from an ethnological perspective, behaviour, and lifestyle of occupants to seek their possible adoption in future buildings to enhance the interaction between human and space which surrounds them that contributes to comfort and better use of domestic energy. A conceptual model is built which relates the position of sunlight in the vernacular houses and occupants' movements during day. The findings from this work will offer a re-conceptualisation of future living spaces that benefit in making spaces more adaptable and resilient.

2. Light and Urban Space Interplay

Links between daylight and energy conservation has been broadly studied, so too the psychological and physiological implications of 'managed' natural light (Ander, 2003, Amundadottir et al., 2017, Custers et al., 2010, Heschomg, 2002, Konis, 2017, Littlefair, 1990, McKennan and Parry, 1984, Ne'eman and Hopkinson, 1970, and Veitch et al., 2008). Managed daylight can improve occupants' mood, awareness of space, productivity and mental health and reduce stress and anxiety. Prior to 1940s, daylight was the primary light source in buildings. Today, electricity is vastly utilised to satisfy most of the occupants' indoor lighting demands. Recently, energy and environmental concerns have attracted the attention of built environment researchers working on daylighting and its potential economic benefits (Bodart and Herde, 2002, Hunt, 1979, Hee et al., 2015 , Ihma and Krartic, 2009, and Pellegrino et al., 2017). The previous research has mainly been driven by the resilient and renewable sources of domestic energy agenda, but also has attracted the attention of other disciplines in exploring links between natural light and human body-behaviour-perception as a function of architectural forms in a variety of spaces including offices, schools, retail, health care facilities and industrial settings.

The Persian traditional architecture exploits the natural light to form and shape integrated interior spaces (Pirnia, 1992). A wealth of studies is available in literature on the use of daylighting in vernacular buildings of Iran in functional, decorative, and spiritual contexts. The symbolic and metaphorical aspects of light and its interplay with the Iranian ideological views are discussed in Ardalan and Bakhtiar (1973), Ahani (2011), Arjmandi (2010), Ayvazian (2004), Bemanian (2011), Corbin (1993), and Mahvash (2006), Javani et al. (2010),. Daylighting strategies in Iranian architecture, especially in traditional houses in hot-and-arid climates, are explored in Moosavi (2014), Maghsoudnia et al. (2015), Nabavi et al. (2013), and Panahi et al. (2013). Chandel et al. (2016) presented a state-of-the-art review of links between energy efficiency and vernacular lighting. Implications of openings and consequent spatial qualities through varied levels of luminance were studied in Arjmandi et al. (2010), Reinhart and LoVerso (2010), and Vanhoutten et al. (2015).

Nevertheless, a comprehensive and structured approach in the study of light in traditional Iranian architecture and its association with occupants' response has to-date received little attention. The implications of presence, absence and changing patterns of light on people mobility and adjustment has remained a matter of dispute. The adoption of vernacular forms in contemporary time has declined, if not fully abandoned. This can probably be due to limited available space per head on urban sprawl and commercial pressures on mass construction, yet lessons from a systematic study of traditional systems can facilitate exploitation of natural daylight energy and in this, contribute to the sustainability agenda.

3. Benchmark Buildings and Methodology

3.1 Benchmark Buildings

A rectangular polygon accommodating 3 historical courtyard houses was adopted for this study. The polygon was located at the heart of Kashan City (BWks climate – see 3.1.2 for details), 220 km south of the Iranian Capital, and approximately sizes 950k m^2. At the north west and north east corners, the site is bordered to 33°58’51.0”N 51°26’47.5”E and 33°58’33.7”N 51°26’05.3”E, respectively. The polygon is bordered to 33°58’13.4”N 51°26’19.1”E from south west and 33°58’24.7”N 51°27’03.3”E from south east.

3.1.1 Historical Background

Kashan is within the highly urbanised Isfahan metropolitan county of Iran. The remainder of the vernacular urban fabric of Kashan dates to developments during the Seljuk (early 9th to late 10th century i.e. 1037-1194) and Safavid eras (early 16th to mid-18th century i.e. 1501–1736). More recent buildings data back to the 19th century (Qajar era). That architectural fabric then began to decline during the 20th century Pahlavi era. Buildings are built with masonry mud or baked brick. The three historical buildings used in this study are: A. Tabatabaei House (N 33.97478 E 51.43918), built in the early 1840s; B. Bani Kazemi House (N 33.976126 E 51.443338) built in 1820s; C. Abbasian Mansion House (N 33.976326 E 51.440235) built in 1870s.

3.1.2 Location and Climate

The Köppen classification suggests four climatic zones for Iran: hot and humid (A), hot and arid (B) - representing 60% of Iran’s landmass, mild and humid (C), and cold (D). The climate class B breaks down further into desert hot-arid (BW) and steppe hot-arid (BS). These collectively form four subdivisions of BWhs, BWks, BSks, and BSKs; ‘s’ refers to dry summer, ‘h’ to hot and ‘k’ to cold. Kashan, the study site, fits in the BWks mesoclimate class. The region is acknowledged for the straight and rather strong sunlight radiation year-round (Figure 2a), cold and dry winters, and warm and dry summers (Figure 2b). The maximum temperature can reach levels as high as 45 Celsius degrees over hot seasons and between 20 to 30 Celsius degrees over cold seasons. Sharp variations in temperature between day and night time is not uncommon to the region. The relative humidity varies between 30 to 60 percent (Also see Koch-Nielsen, 2013). To tackle the high intensity of sunlight, local architects tend not to allow the direct light into interior spaces through making use of ‘eluding’ components. Interior space is illuminated through the reflected light from mirror works, mosaic works or water surface. Direct sunlight is allowed in only through a limited number of openings and after passing through wooden/stone latticed windows covered with coloured glasses.

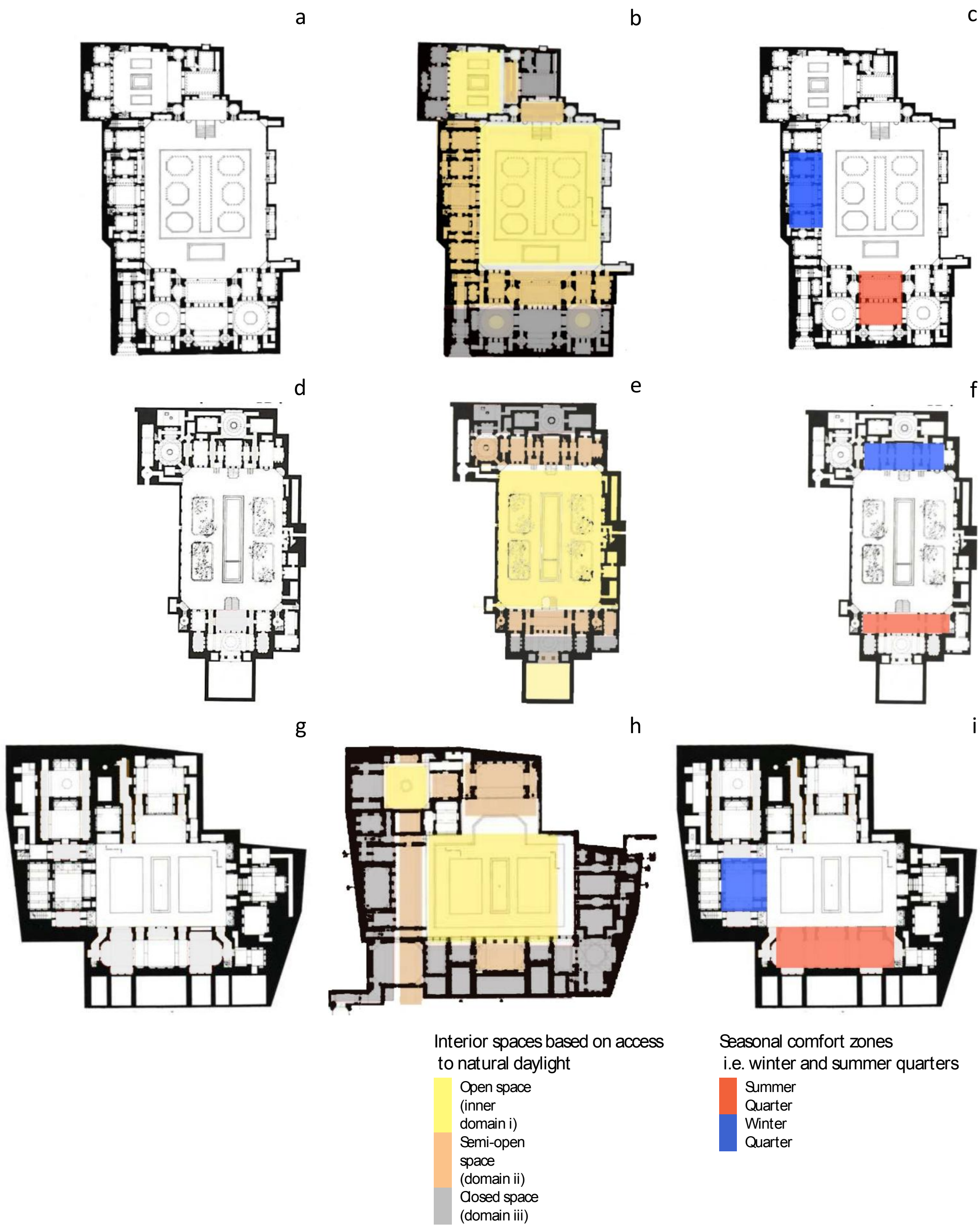

Figure 1. Plan view of the three study buildings - [a], [d], [g]: plan view of the three study houses i.e. Tabatabaei, Bani Kazemi, Abbasian; [b], [e], [h]: the three conceptual interior space domains based on daylight intake; [c], [f], [i]: seasonal comfort zones (based on archival studies, observations, and processed plans in Farokhyar, 2013)

Buildings are commonly rectangular and striking North West (NW) to South East (SE). This axis arguably allows the best position, supplying just enough shade in summer days and heat over winter (Pirnia, 1992). The majorities of traditional buildings look inwards. The entire space is arranged around an open, rectangular courtyard that connects (i.e. effectively bridges) different elements of the house. Distributing built spaces around the central courtyard should improve the indoor air quality and daylighting.

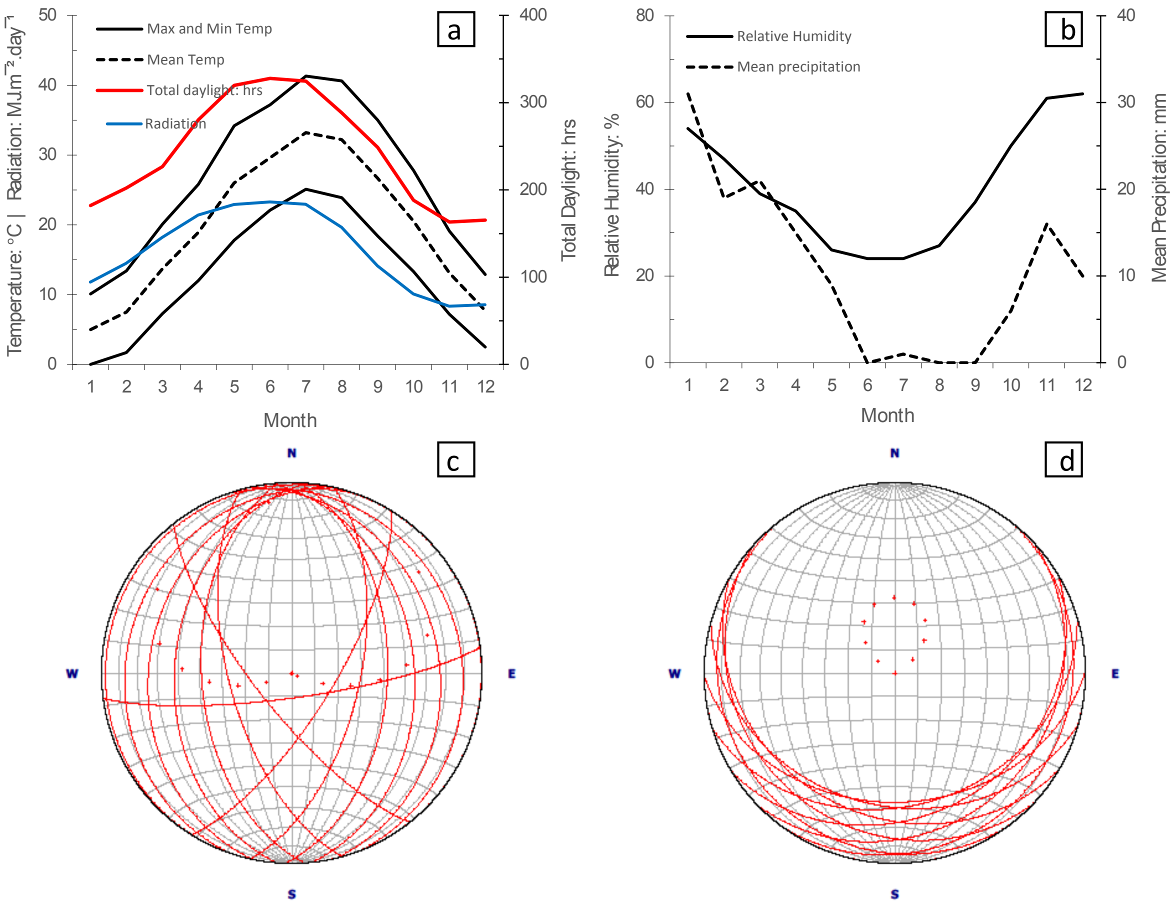

Figure 2. Variation throughout a year of [a] temperature, radiation, and total daylight [b] relative humidity and mean precipitation; stereonet projection (equal area Great Circles and Poles) representing the hourly position of sun throughout a day over [c] summer warm season (21 June) [d] winter cold season (21 December) – developed by authors

3.2 Methodology

Archival desk study is first used at scoping phase to better understand the harmonised space - human - environment architectural systems, and to formulate questions to be posed to a group of interviewees. Walk-over survey i.e. field investigation is then pursued to refine the findings through observation. Six standard questions are designed and provided to the interviewees. Eleven interviews were recorded, compiled, and followed by a short question and answer session to build on evidences and clarify points where needed.

A range of former/current residents and urban design practitioners were targeted for interviews: two senior citizens (who used to live in one of the study buildings during the 1940-50s), two current residents in courtyard buildings within the study polygon, one architect, two psychologists (with an interest in interaction of light and human), two historians, and two urban planners in Kashan district council. The adoption of such a diverse group is consistent with the diversity of disciplines involved in urban interior design of responsive systems. Current resident interviewees were asked to fill in a daily logbook, mapping out their movements and activities in a typical June (representing the warm season) and December (representing the cold season) day. They were asked to make the least possible use of electricity/heating throughout the period of study day and adapt their activities to natural daylight. The interview questions are listed below:

(a) Explain the daily activities and movements of occupants in relevance with time and ambient temperature, throughout a typical day

(b) Could seasonal thermal gradients have a detectable effect on user's perception of space and consequently movements?

(c) On the provided plan view of three study buildings, can you relate time with occupants' common and individual activities?

(d) How contentment relates to the thermal and visual comfort, in the context of the study buildings?

(e) How the architectural forms relate to the wind and light perception, in the context of the study buildings?

(f) How wind and light perception relates to occupants' behaviour and their choice of space, in the context of the study buildings?

(g) Could the heating and electricity energy supply in the historical buildings combined with occupants' modern-day demands promote or hinder the use of managed natural daylight to address part or entire demands of occupants to their thermal and visual satisfaction?

4. Vernacular Structures: Observations and Analysis

The study houses shared the typical 19th century Isfahani architectural form in consisting of two internal and external quarters. The main components include: entrance, central courtyard (pool and garden), Eivan and rooms (reception rooms, living rooms, private rooms, kitchen and services (see Pirnia, 1992). Figure 3 illustrates the plan drawing for House 'a' i.e. Tabatabaei House.

The entrance (vestibule) is an octagon or semi octagon space that mainly directs the access to central courtyard. Corridor (Dalan) is a narrow passage that guides the entrant from porch to the yard. This maze corridor provides privacy to the house. The central courtyard (Hayat) is an open-air common space mainly for socialising and reception. The planted greeneries (cooling media on evapotranspiration) around the central shallow pond enhances the interior air quality and indirectly lightens the interior space. Courtyards were usually designed in rectangular shape and positioned at the centre of the house to function as an interface space between the interior and exterior parts. The high length to width ratio used in their design allows occupants to reside in shaded spaces (towards south) during summer days. Terrace (Eyvan) is a semi-open space, often a three-side closed corridor in front of bedrooms that is typically used to create shady and cool clusters. Terrace (Ravagh) is similar to Eyvan in many ways, but essentially is a semi-open colonnade in the courtyard. As such, Ravagh and Eyvan count as both public and private arenas, suited for family gatherings with the potential to be expanded into each other. These are commonly oriented to the south. South and east oriented 'Eyvans' offer very cool and shady places, suitable for summer afternoons. Rooms are located around the courtyard. Hall (Talar) is the largest room, used to for special events and guests. Living room (Talar) is used for gathering of residents and visitors. These can appear in three forms: Haft-Dari (seven doors), Panj-Dari (five doors), or Se-Dari (three doors) rooms. Smaller private rooms are closed from three sides and open from one side (towards open/covered areas). Installation of transparent elements including coloured glasses and porous walls appears to have assisted these spaces in attracting the natural light. Bedrooms are fitted with eastern windows to capture the morning light. Kitchen is usually located near the water wells. Storage spaces with no primary usage are in the eastern side of the courtyard. These spaces mostly receive light through the roof openings rather than opening toward the courtyard. Bathrooms are in the lower level of the houses. A key element that is widely used to reflect and direct the light to the internal layers is water. Pool houses are traditional dwellings containing a central layer around which different functions are formed. These spaces have the capability to receive the light from two sides: the open space or covered area and skylight (ceiling openings). Sufficient headroom for these spaces allow them to receive light from the apertures installed on domes (i.e. ceiling system). The light from above shed on pool and reflects, from water in the pool, to lighten the surroundings.

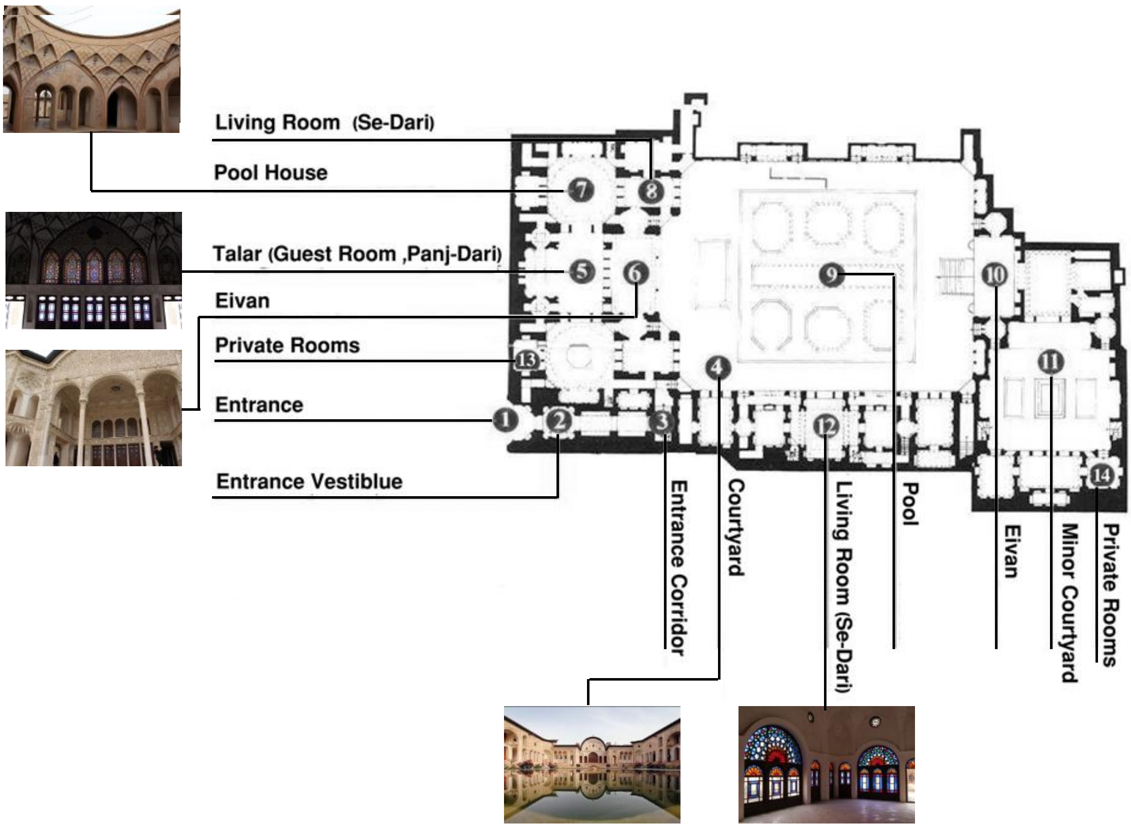

Figure 3. Typical plan – Benchmark house ‘a’: Tabatabaei (Farokhyar, 2013 with modifications)

The indoor areas can conveniently be divided into three core domains (i.e. quarters), based on lighting levels. The first domain (i) is the nearest indoor space to the openings and receives the daylight directly from the central courtyard. This space has the greatest potential to pass the light to surrounding spaces (i.e. buffer zone i-ii). The second domain (ii) receives the light from the first domain, so too the natural light from wall openings. This space is generally considered as a mediate space for sharing the light. The third domain is effectively a receptor of light from domain ii, as well as small apertures on the ceiling. Figure

4a and 4b illustrate plan and elevation view of study house 'a' (Tabatabaei) and the spatial distribution of light through the three interior domains. This is the backbone of the conceptual model to be introduced and discussed in the following section. This data is coupled with the surveyed occupants' behaviour (particularly movements - from interviews) to plot the occupied interior areas during the course of day and across the three main space domains in Figure 4c (for Tabatabaei House as benchmark). The buffer zone appears to be the only domain which accommodates occupants at all times.

The pool at the heart of house appears to be the main source of indoor light. Given the fact that light, as an isotropic medium, emits from the central courtyard into the interior spaces, daylight's reach and direction is plotted in Figure 5 for the three historical buildings for cold and warm season. The northern side of buildings appear to attract the least radiated light all year round.

Figure 4. Tabatabaei benchmark house - [a] direction of daylight from courtyards to interior spaces – plan view; [b] Elevation view; seasonal spatial distribution of occupants over the course of day [c] Summer season [d] Winter season (Farokhyar, 2013 with modifications)

Drawn out from archival studies (Naraghi 1966 and Rajabi 2009) and interviews, the basement and ground-level spaces south of the building used to host occupants to a greater extent during the warm season, from morning to noon. Courtyard area accommodated occupants over afternoons. During the cold season, (i.e. winter), rooms to the north hosted people more during both day and night time. The latter movements probably established a symbiotic relation between occupants and the interior built environment, in occupants adopting their space at a time in relevance to the natural light.

5. Conceptual Model

Urban interior living space is multi-domain and multifunctional: in short, they represent a complex web of independent but interrelated (via lighting) domains. A change made to light pathway, pattern, colour, source or openings orientation is likely to result in impacts on occupants' lifestyle style in many ways, and it is not always clear what these impacts might be. A simple conceptual model is discussed in two parts: the interrelationship between three core space domains of traditional vernacular style as identified from the archival and field studies combined (Figure 1); and daylight penetrating into each domain that affect energy efficiency via occupants' movement (Figure 5). Figure 6 describes how well the indoor directed light within the three core domains affect people, how these enhance or lower as buildings, systems of systems, attempt to become more resilient and sustainable. Although archival studies often suggest a historical tendency towards the deliberate controlled exposure to light in the inner domain (i.e. overlooking central courtyard), observations uncovered the role of managed light in drawing together or separating domains. Where two domains align (e.g. the inner and middle domains), they are most likely to operate effectively to facilitate the space achieve its purpose. Two questions are set here: Can directing the interior light put a control on people (occupant or visitor) autonomy (in entering spaces). Can light work towards or against cohesion between indoor core space domains?

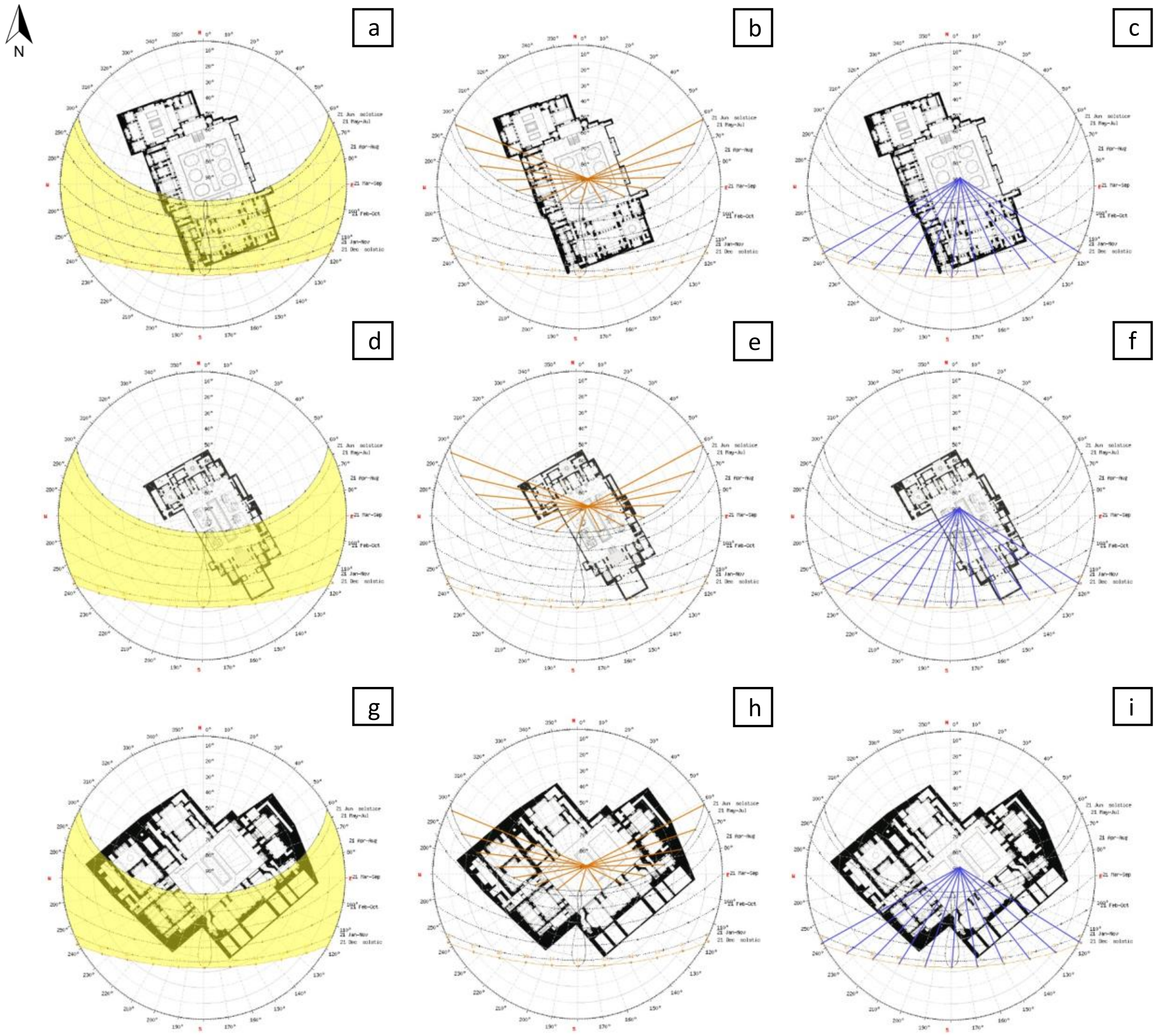

Figure 5. Radiation of sun from courtyard into the closed space - [a], [d], [g]: Relative position of sun June to December; [b], [e], [h]: patterns of radiation from courtyard in June (warm season); [c], [f], [i]: patterns of radiation from courtyard in December (cold season) – [IRIMO data processed]

The perception of what constitutes the interdependency – and consequent implications – of climatic-responsive vernacular buildings are divers, often conflicting and varying across disciplines. Here, there is ample evidence to suggest that of the interaction between reflected light from central courtyard and indirect lights from wall openings in the buffer domain i-ii is not managed, the interior space will probably be required to accommodate more physical elements (to achieve the intended cohesion-separation); and this in turn will involve in generation of smaller spaces and consumption of more energy (for ventilation, cooling/heating, and lighting purposes). This is undesirable, given that households are already stretched in terms of resource availability. The view – broadly held and repeatedly appeared in the literature – that occupants/visitors i.e. people organically move between interior spaces over 24 hours and warm/cold seasons is here contended and countered by a tendency of people to reside and remain in the buffer i-ii zone, to benefit from its symbiotic act with the surrounding spaces and the steadier temperature/humidity (Figure 4c, 4d and 6b).

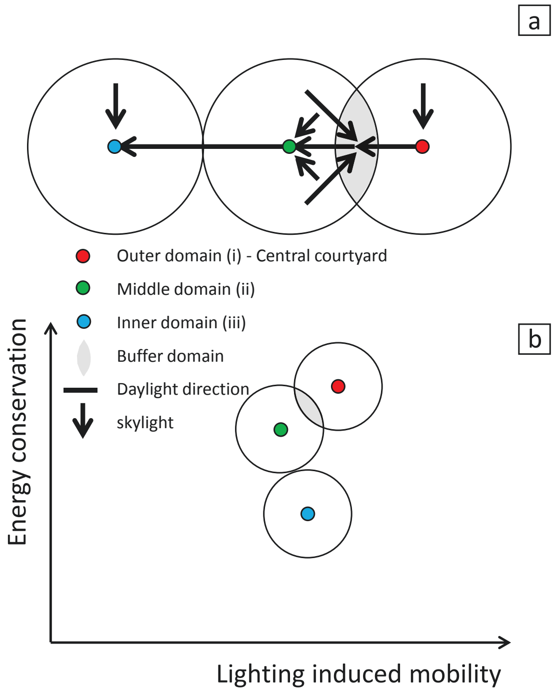

Figure 6. [a] three conceptual domains in a Vernacular form and exchange of light between and across the domains [b] movement towards climatic adaptation and its association with energy conservation for the three conceptual domains (developed by authors)

6. Concluding Discussions

The 'globalised' modern architecture, by-and-large, supplies energy (and light) to interior spaces from often unsustainable resources. Consequently, and in absence of natural elements, occupants of modern living spaces have a far lower interaction with their surroundings. With growing population and limited resources, energy conservation has become a grand global challenge. To address that challenge, the common practice is directed toward the use of renewable resources or low consuming systems.

Attached to the tenets of the traditional and hot-and-arid regional architectural forms in Iran, and its symbiotic integration which nature - mainly to exploit and harvest natural energies - is the question of whether the modern architectural forms can benefit from those principles and re-establish the interconnectivity between inhabitant's behaviour, interior design, and 'engineered' natural light. This also begs the question of whether contemporary architectural forms should be centred around occupants, allowing occupants to adapt themselves with daily and seasonal variation of climate. Whilst regional and cultural constraints retain the viability of such an approach a matter for debate, there is no doubt

that the interconnectivity of systems will facilitate the design and development of more sustainable built living spaces.
We took evidence from a wide range of those for whom vernacular buildings provide the focus of their activities (current and former residents, architects, psychologists, city planners, and historians), and distilled the findings into a concise, conceptual model and illustrates our understanding of the light – space – human interaction and also needs of and aspirations for urban living spaces. To illustrate benefits of this enhanced knowledge, a simple conceptual model for present-day urban living spaces is presented. Figure 7 presents the hypothesised conceptual model for a pair of urban flats arranged around an open central courtyard space.

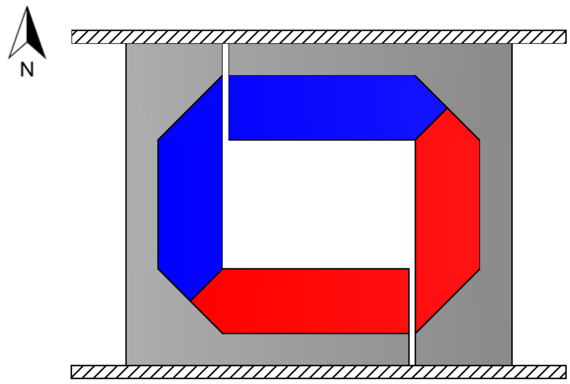

Figure 7. Central courtyard surrounded with pair of urban flats each containing the three main domains (developed by Authors)

The conceptual model in Figure 7 suites low rise residential buildings, constrained from North and South. Two flats are considered at each level. Flats are suggested to surround a central courtyard. The size of courtyard varies but would be greater than that of typical lightwell patios. The flat on the right side harvests natural light from east, and west, and south. The flat on the left harvest light from north and west and east. Sitting rooms and social interior spaces are accommodated towards the courtyard. This allows a degree of flexibility to the sitting rooms, through encouraging residents to adapt to natural light, daily and seasonally, through adjusting the location of furniture. Benefitting from an enhanced level of awareness, residents indirectly interact with light and adapt themselves with sun radiation variations. Such human response will in turn relax the dependency on the domestic fossil fuel derived energy demands.

7. Conclusions

Human, time, and natural light interact and assessing the implications of that interplay within urban indoor living spaces (in terms of light intrusiveness, spatial coverage and pattern, and extent) plays a vital role in supporting architectural design for enhanced sustainability performance. Contemporary urban buildings do not necessarily cater well for a future of limited resources and energy, raising the cross-cutting question of how interior designers and architects should act to ensure space, environment and people function symbiotically to provide resilience, wellbeing, and sustainable energy consumption.

This work revisited, at some length, the traditional Iranian-Isfahani architectural forms and proposes, on the basis of field observations - in conjunction with historical readings and interviews - that there exists a link between the daily/seasonal use of spaces and level of direct and reflected light in interior spaces. The various forms of space usage are controlled by light conveyance installations (in three levels), and the relative layout and shape of interior spaces. Installation and interior layouts adopted in this traditional architecture have had effectively offered a sustainable alternative solution to cooling and lighting demands through, passively, encouraging inhabitants to adjust their movements and activities, on hourly and seasonal basis, with 'engineered' natural light. It is also proposed that the benefits of traditional Iranian architecture are fractal, and hence applicable for modern and often smaller living spaces. We offer conceptual models for the vernacular traditional buildings and their potential use in the contemporary design. The model tends to demonstrate how Persian vernacular style accommodated large families and supported their wellbeing and energy demands. The prospect of using this model as a vehicle to adopt traditional forms in contemporary urban indoor architecture may beg the question of scale. To mitigate this, the presence of a buffer domain is discussed that benefits from steady flow of air, moderated temperature, and lighting levels. The buffer domain naturally accommodates residents and visitors across seasons and through day time. The peculiar combination of light generates a natural barrier between that buffer zone and the middle domains, which can cater the residents and satisfy privacy.

Drawn from the presented model is set of recommendations that we feel are the most important to put to architectural designers who lead the thinking on bother their occupants and the energy infrastructure that supports their wellbeing. Advocated recommendations are:

- working towards architectural designed informed by daylight (position, intensity, reach and direction) to allow better access to various levels of light and temperature at any time and at various interior spaces,
- working towards design of flexible spaces that adapt with changing climatic conditions throughout a year,
- working towards a better symbiosis between occupants' daily movements, time, temperature, and levels of illumination,
- putting measures to facilitate the better awareness of occupants of light-space-time-human interplay and implications in the context of energy conservation.

References

Ahani, F. (2011). Natural light in traditional architecture of Iran: lessons to remember. (pp. 25-36). WIT Transactions on The Built Environment.

Amundadottir, ML., Rockcastle, S., Khanie, MS., and Andersen, M. (2017). A human-centric approach to assess daylight in buildings for non-visual health potential, visual interest and gaze behavior. *Building and Environment, 113*, 5-21.

Ander, GD. (2003). *Daylighting Performance and Design, 2nd Edition.* John Wiley & Sons.

Ardalan, N., and Bakhtiar, L. (1973). *The Sense of Unity : The Sufi Tradition in Persian Architecture.* University of Chicago Press.

Arjmandi, HT. (2010). Application Of Transparency To Increase Day Lighting Level Of Interior Spaces In The Dwelling Apartments In Tehran–A Lesson From Iranian Traditional Architecture.

Ayvazian, S. (2004). Light in Traditional and Islamic Architecture of Iran.

Bemanian, MR. (2011). Assessing the effect of light on the space sequence in Islamic Architecture. *Islamic Architecture and Urban Development*.

Bodart, M., Herde, AD. (2002). Global energy savings in offices buildings by the use of daylighting. *Energy and Buildings, 34*, 421-429.

Bonine, ME. (1980). Aridity and structure: adaptations of indigenous housing in central Iran.

Chandel, SS., Sharma, V., and Marwah, BM. 2016. Review of energy efficient features in vernacular architecture for improving indoor thermal comfort conditions. Renewable and Sustainable Energy Reviews. 65. 459-477.

Corbin, H. (1993). *History of Islamic Philosophy.* Kegan Paul International.

Custers, P., Kort, YD., IJsselsteijn, W., and Kruiff, MD. (2010). Lighting in retail environments: Atmosphere perception in the real world. *Lighting Research and Technology, 2*, 331-343.

Farokhyar, H. 2013. Hundred houses, hundred plans (The Architectural Forms of historical Buildings in Arid and Hot Climates. Free Islamic University (Kashan) [in Farsi]

Fitch, JM. (1972). *American Building: The Environmental Forces That Shape It.* Boston: Houghton Mifflin

Hee, W., Alghoul, M., Bakhtyar, B., Elayeb, O., Shameri, M., and Alrubaih, M., (2015). The role of window glazing on daylighting and energy saving in buildings. *Renewable and Sustainable Energy Reviews, 42*, 323-343.

Heschong, L. (2002). Daylighting and Human Performance. *ASHRAE Journal;, 44*, 65-67.

Humphreys, M. (1995). Termal comfort temperatures and the habbits of hobbies. *E & F N Spon*, 3-14.

Hunt, D. (1979). Improved daylight data for predicting energy savings from photoelectric controls. *11*, 9-23.

Ihma, P., Nemrib, A., and Krartic, M. (2009). Estimation of lighting energy savings from daylighting. *Building and Environment, 44*, 509-514.

Jahanshahi, S. (2015). The collection of mosque patterns with light hierarchy approach to perception space of architecture (Case Study: Ganjalikhan Mosque and Sheikh Lotfollah Mosque). *Journal of Scientific Research and Development*, 174-180.

Javani, A., Javani, Z., & Moshkforoush, M. (2010). Studying Relationship between Application of Light and Iranian Pattern of Thoughts. *Color and Light in Architecture*, (pp. 39-46). Verona.

Koch-Nielsen, H. (2013). *Stay Cool: A Design Guide for the Built Environment in Hot Climates.* Routledge.

Konis, K. (2017). A novel circadian daylight metric for building design and evaluation. *Building and Environment, 113*, 22-38.

Leaman, A., & Bordass, W. (2000). Productivity in buildings: the killer variables. In D. Clements-Croome, *Creating The Productive Workplace.* London: E and FN Spon.

Li, DH., and Lam, JC. (2003). An investigation of daylighting performance and energy saving in a daylit corridor. *Energy and Buildings, 35*, 365-373.

Littlefair, PJ. (1990). Review Paper: Innovative daylighting: Review of systems and evaluation methods. *Lighting Research and Technology, 21*, 1-17.

Peel, BL. (2007). Updated world map of the Köppen-Geiger climate classification. *Hydrol. Earth Syst. Sci., 11*, 1633-1644.

Maghsoudinia, E., Hajihasani, T., Yunos, MY., and Rahman, NA. (2015). Daylighting Strategies in Iranian Vernacular Residential Buildings in Hot and Dry Climate. *Applied Mechanics and Materials, 747*, 329-332.

Mahvash, M. (2006). The Qualitative Presence of Light in Architecture: Processing the Space with an Emphasis on Iranian Mosques. *University of Tehran*.

McKennan, G., and Parry, C. (1984). An investigation of task lighting for offices. *Lighting Research and Technology, 16*, 171-186.

Memarian, GH. (2008). *An introduction to Iranian Residential Architecture: Introverted Typology.* Tehran: Soroush Danesh.

Moossavi, SM. (2014). Passive Building Design for Hot-Arid Climate in Traditional Iranian Architecture.

Nabavi, F., Ahmad, Y., and Goh, AT. (2013). Daylight Design Strategies: A Lesson from Iranian Traditional Houses. *Mediterranean Journal of Social Sciences*.

Naraghi, H. (1966). *The Social History of Kashan.* Tehran: University of Tehran Publication.

Ne'eman, E., and Hopkinson, R. (1970). Critical minimum acceptable window size: a study of window design and provision of a view. *Lighting Research and Technology, 2*, 17-27.

Panahi, S., Mirzaei, Q., and Mohammadikia, M. (2013). Comparative Analysis of Natural Elements in the Architecture of Tabriz and Kashan Houses (During Qajar Era). *Middle-East Journal of Scientific Research, 13*, 507-517.

Pellegrino, A., Cammarano, S., Verso, VR., and Corrado, V. (2017). Impact of daylighting on total energy use in offices of varying architectural features in Italy: Results from a parametric study. *Building and Environment, 113*, 151-162.

Pirnia, MK. (1992). *Iranian Islamic Architecture.* Tehran: Soroush Danesh.

Rajabi, P. (2009). *Kashan, the Jewell of Iran's History.* Tehran: Pejvak Keyvan.

Shaterian, R. (2013). *Climate and Architecture.* Tehran: Simaye Danesh .

Soroush, MM. (2012). The impact of Al-Nour Sura on the Architecture of Sheikh Lotfollah Mosque. *Second National Conference on Islamic city.* Isfahan: Isfahan Municipality.

Veitch, J., Newsham, G., Boyce, P., and Jones, C. (2008). Lighting appraisal, well-being and performance in open-plan offices: A linked mechanisms approach. *Lighting Research and Thechnology, 40*, 133-151.