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COMMENTARY ON CASE STUDIES

Strategising Ergonomics Sustainability: Reviewing Passive Design Approaches and Its Applications for Humane Design

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Abstract: This paper brings together classical principles of sustainable design to frame perspectives and arguments for humane design in reducing environmental impacts. Research will focus on the application of ergonomic principles in the processes of choosing materials and built construction, and to discuss the impact of integrating climatic and humane design strategies. The case study compares application of three pioneering sustainable architecture. The basis of this interpretive case method of research enables a contemporary reinterpretation in ergonomics sustainability while enhancing perspectives on passive design opportunities still valid today. The main objective of study is to examine several questions: What key architectural issues cause negative environmental impacts? How are fundamental elements of passive design be applied in developing sustainable ergonomic architecture designs without compromising future resource needs? An American case study is presented. The primary assessment method is an analysis of the ways in which the principles of economy of resources, lifecycle design and humane design are incorporated into the architectural concept and planning. It is hoped the analysis leads field practitioners to seek environmental solutions for built construction methods and technologies, while consciously adopting a pro-environmental strategy in sustainable architectural design planning.

Keywords: Architectural Design, Construction, Humane Design, Passive Design, Sustainable Ergonomics

1.0 INTRODUCTION

Architecture and construction are two branches of industry that produce the most conspicuous, tangible outcomes of human development, but the impacts and footprints left behind in the processes to create buildings and built environments are not always visible or sustainable. Built designs must firstly be aligned with local building laws and policies, but the real costs of materials extraction, manufacturing, production, and supply for projects, together with water, electricity, geographical site, and climate data, are complex measures of sustainable design achievement [1]. Additionally, sustainable design research urges for increasingly rigorous objectives to be set for *ergonomics* or *human-centred*, architecture. In achieve these objectives, evidence-based empirical findings from the fields of physics, biochemistry, engineering, environmental and life sciences, design process technologies and human psychology, involves in-depth user testing, perception research and multisensorial experimentations [2]. It can be inferred from these challenges, that inadequate understanding hinders the architectural and construction industry's objective to balance sustainability and achieve the economic, environmental, or social goals. Efficiency itself is a concept that derives from sustainability principles, from transportation to energy use to promoting occupants' personal and social health and ensuring quality housing are constructed with minimal pollution, emissions, and waste disposal considerations. For architects, efficiency is a key outcome from proper construction planning to site management and achieving long term outcomes of building projects. Ergonomist from University of Naples Federico II Italy, Prof Erminia Attaianese [3] believes these issues have driven concerns among designers and architects seeking a reinterpretation of sustainability, more than three decades after the framework attained widespread attention and adoption.

In reviewing the role of human-centred design for sustainable built environments, the research questions for this study include: *What critical factors drive ergonomics and humane design considerations for sustainable architecture? What aspect of ergonomics reflect passive design methods in achieving sustainable design goals?*

2.0 BACKGROUND OF THE STUDY

The World Commission on Environment and Development defined sustainability as the ability to "[meet] the needs of the present without compromising the ability of future generations to meet their own needs" [4]. This view of sustainability continues to be relevant, but at the same time, it enjoins global stakeholders to practice the right actions and activities in reaching these collective objectives, and to demonstrate their willingness to embrace the values of sustainability that would protect what remains of global natural sources.

Architectural design which spans the aspects of planning, design, construction, management and impacts of buildings, provides an excellent opportunity for sustainability assessment. This process begins from questioning varied situational contexts such as building function, to understanding how to control the variables of human interactions within the natural and designed environment [3]. One practical way to scientifically design, implement and assess environmental sustainability is in the application of ergonomics.

2.1 Significance of Ergonomics Research

In *Bodyspace*, Stephen Pheasant and Christine M. Haslegrave [5] defined ergonomics as an applied discipline where the variables of one's environment, location choice, available resources, the cost-benefit trade-offs of materials, issues of health, wellbeing, productivity, and the elements related to space functionality as the built dimensions (known as *anthropometries*), integrate into the overall goal of ergonomics as a branch of empirical science.

Ergonomics today is redefined as the discipline that applies design methods and solutions to practical built systems to enhance ways humans interact with such systems, in order to *improve performance while assuring safety, comfort and overall performance quality* [6]. The UK CIEHF has been instrumental for developing the discipline of ergonomics during the growth of industrialisation systems and mass production environments from the 1940s. Embracing a view of scientific and technical applications to enhance human performance and productivity, ergonomics practice has greatly flourished, in large part attributed to proponents' emphasis on *human factors*, assuring equipment functioning and use is potentiated, while recognising how equipment and user interactions affect human behaviours, physiology and psychology in an increasing range of modern industrial and workplace environments, and this determines the effectiveness of product designs in improving cognitive functioning, from computers to vehicles, dwelling places and public environments such as roads [6].

Due to cross-disciplinary pedagogical development over decades, current sustainable architectural approaches are strongly reflective of antecedent classical architecture's inclination towards passive designs [7]. Once the domain of modernist architectural scholars proposing practical solutions beyond structural aesthetics, ergonomic built spaces today are conceived as "instruments of healing", using less resources and energy, preferring stripped down proportions, processes and techniques that optimise performance and minimises environmental footprint with purposeful lighting, balanced airflows and less wasteful elements justifying its urbanist concept [4].

Remijn [8] stresses sustainable schemes of design to consider end users' direct input about operational effectiveness which applies traditional spatial designing of the physical environment. He developed an *Ergonomics Model* involving "user participation" (Table 1).

Problem Definition	Expectations and exploration of what benefits the ergonomics layout offers.
Analysis	Tasks and objectives fulfilled when system or layout is fully operational.
Design	Functional solutions for interaction, task allocation and future task requirements
Implementation	Construction of infrastructure after decisions on structural, mechanical, materials and other requirements are made.
Evaluation of Operational Efficiency	Review of ergonomics functions and improvements as necessary to support basic infrastructure already in place.

Table 1: Ergonomics Model of Spatial Design Planning [8]

2.2 Architecture and Ergonomics

Architecture represents a unique branch of fine arts in the nature of the creative process, combining aesthetics and functionality to extend our human cultural language. Architects use visual planning to express the structure's message, emotions, and stories. This begins from understanding *materiality* using cognitive and multi-sensorial insights on construction material and design decisions [9; 2].

Increasing pressures are laid on the construction sectors to develop long terms solutions and alternatives to unsustainable development, including systems and processes that reduce fossil fuel energy consumption, emission of ozone-thinning gases such as carbon dioxide, methane, and hydrofluorocarbons, resulting in temperatures rising, affecting humans and ecosystems. In tandem with these issues is the scorn poured by lobbying stakeholders such as NGOs [10] who impose stringent socioeconomic expectations on architects and developers.

As a result, the processes of construction are driven by ever-higher standards for greener built environment, whether mandated by law, regulated by policies, or recommended under professional accreditation guidelines [9; 11]. Attaianese [4] urges for the holistic integration of assessing *human* *behavioural outcomes* in regards economic and functional (physical) performance and social wellbeing as instrumental in developing *sustainable building performance* guidelines and indices for assessing environmental control, land and space use, and energy efficiency [4; 12].

2.3 Cultural Ergonomics

Ergonomics is cited within the greater cultural transformation milieu of changes to work and social systems. Mooted by twentieth century engineers studying technological impact on human-technology transfer and the complexity of designing performance-driven interfaces among developing industrialised countries, cultural concerns coalesced into a publication by Michael Kaplan in 1991, who elaborated on this concept to better define the role of ergonomics in work systems design to study "cultural variations" in the technology of design [13]. Cultural factors show the key interactions between humans as they interface with living areas within the settings and boundaries of cultural groupings, large and small, such as personal workspaces, homes, office, leisure, and public environments. Karwowski [14: 27-31] considers cultural ergonomics as an applied extension of engineering design, psychological science, and cognitive anthropology, in adaptation to modern technology design and utilisation in workspaces. Spatial distance, lighting, visibility, heating, noise, and emerging aspects of living environments such as adaptation to cultural diversity, are key factors affecting behavioural characteristics of users [14].

Literature and research publications show a patchy contribution of ergonomics to cultural space planning in the architectural design process. In response, many researchers stress a greater symbiosis of public-interest design with interior design, urging cultural elements to lead in the process of designing architectural spaces to achieve sustainable design goals such as community building and cultural symbolisation through adopting passive design strategies [15]. Fundamental approaches to sustainable architecture are framed for ease of introduction in academic settings to future practitioners [16]. These conceptual principles, summed up in Figure 1, aim to foster the foundations for more positive human experiences of living in healthful communities and socially beneficial habitats. Educators aim to express specific architectural concepts, characteristics as well as sustainable built design elements that are used to achieve different objectives.

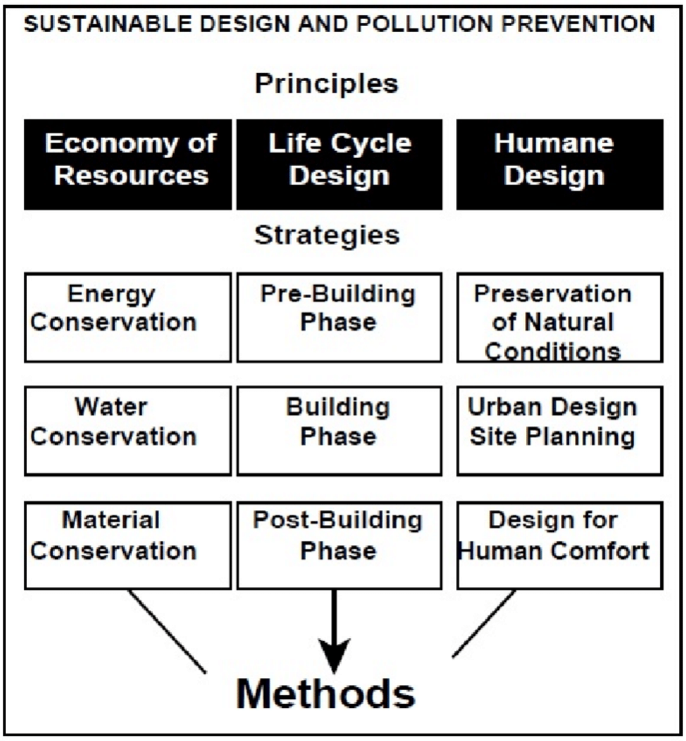

Figure 1: Principles of Sustainable Design in Architecture

3.0 EVALUATION OF THE CASE

This paper now presents a case study of Ripple Design LLC's Courtyard House, built in 2006 in Westwood, Los Angeles [17]. The building, with three bedrooms and 3.5 bathrooms, takes up total floor space of over 2800 sq. ft., built on 6316 sq. ft. land lot, abutting a hillside [18].

3.1 Case Study: Courtyard House, Los Angeles

Architect Thomas Robert applied passive design strategies for a home conceived and commissioned for two separated dwellers. Principles of solar gain and shading, thermal mass and insulation were central in the planning process to ensure Courtyard House performs as an energy-efficient building, through a connecting courtyard (Figure 2).

The control of thermal conditions and ventilation comes from well-positioned casement windows, walls and ceilings. Deep roof overhangs and *low emissivity* (Low-E) window glazing moderates solar gain [18]. Passive ventilation method of window design reduces overall energy consumption by gradually dissipating internal temperatures externally, and welcoming cool breezes within. The living areas of the two respective house sections open to an attached internal courtyard, which doubles as a kitchen [19]. Bifold doors double as moving glass walls, which can be opened and shut to control daylight and heat (Figure 3).

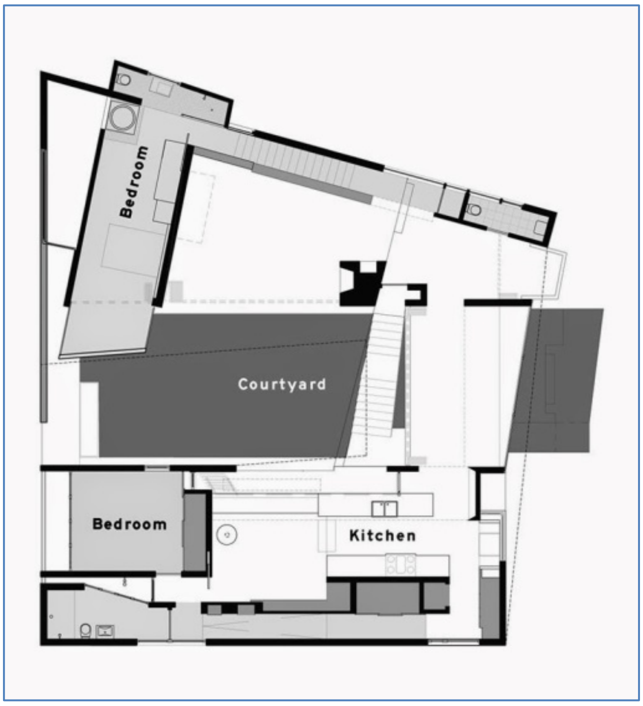

Figure 2: Plan of the Courtyard House

The sun orientation captures the positive impacts of passive stack ventilation design through chimneys with openable roof light to cool the interior and capture natural light from external. Solar gain is controlled via deep sloping roof and the bifold door systems. An aesthetic, interaction-friendly humane design surprise can be found in the knotty-pine bookshelves made from stacked plywood boxes and steel spacers that invite both light and readers. Privacy is found within the two bedrooms; all other aspects are in open settings [19].

The interior walls and ceiling were constructed from thick materials like stucco, masonry which offers natural thermal mass insulation, reflecting daytime heat and sealing heat within during the night, effectively eliminating the need for cooling systems [20].

In the context of the moderately humid annual temperatures which California experiences, the house interior is horizontally designed to maximise natural ventilation. Interior surfaces reflect daylight from the courtyard to reduce usage of artificial lighting (Figure 4). Modernism inspired the architectural design approach, with thoughtful emphasis on open fenestrations which welcome nature indoors, the use of solar panels, photovoltaic cells, and other green technologies [18], and liberal use of warm wooden interior materials sourced locally, such as knotty pine from sustainable pinewood forest [20].

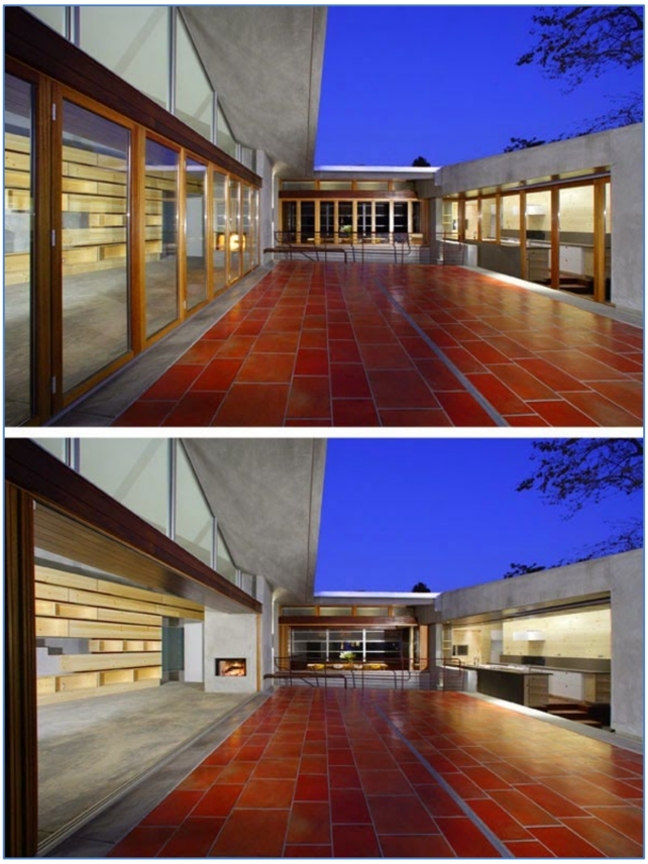

Figure 3: Bifold glass wall system to regulate comfort

England-born architect Thomas Robertson was featured in prestigious architectural design publications upon the completion of this effortful project. This case study shows a clear example of passive design solutions through adapting sustainable architectural design principles to reveal the advantages of natural materials and efficient construction techniques.

Figure 4: Interior surfaces reflect daylight

4.0 PROPOSED SOLUTION

Passive design is a pragmatic conservation solution. One key applied area is in the collection, storage, and filtering of rainwater. Water consumption and economic development have been correlated negatively since increased human needs for clean water and other human activities strain water systems, with ecological impacts that directly causes climate change, resulting in pollution, droughts, and loss of living habitats [16]. Sustainable strategies attempt to overcome increasing environmental problems through applying the principles of water efficiency, water reuse and recycle. For instance, designing roof spaces as rainwater receptacles applies the reuse principle, while underground facilities, along with planting and drainage systems are helpful in storing water for drought periods [21].

4.1 Economy of Resources Studies and Analysis

Sustainable drainage systems effectively control runoffs from roads or other places where rainfall lands. Permeable (*porous*) paving can store large amounts of water temporarily under its surface, and suited for pavements, yards, outdoor car parks, to avoid puddles and pooling, with the bonus of easy cleaning [22]. Plantings on roofs and walls help absorb rainwater and slows water runoffs.

4.1.1 Economy of Resources I: Water Conservation

Water efficiency indoors is attained from installing water saving appliances to replace standard fittings. Hygienic fittings include showers, taps and urinals. Automatic water release from sensors avoids wastage. Eco-friendly appliances like washing machines and dishwashers with water saving features and indoor meters heightens consumer awareness towards conservation [21].

Water reuse and recycling are passive strategies to reclaim rainwater or untreated wastewater (*greywater*) for outdoor water management. Stored rainwater, filtered, could be channelled for outdoor use, or kept in a tank for essential use. Rainwater is suited for irrigating greeneries, providing nutrients that improve soil health. Further down the sustainability chain, greywater treatment includes collecting (*uncontaminated*) wastewater from baths, washing machines, showers, and filters for reuse purposes: to flush toilets or water garden plants. However, caution is advised in greywater reuse treatment systems to ensure health is not compromised [23: 19-54].

4.1.2 Economy of Resources II: Daylighting

Natural lighting as a passive design strategy is a critical organic element to illuminate spaces with less electricity consumption and associated carbon emissions [24]. While a cost-saving measure per se, the ergonomics impact of daylighting is crucial in affecting daily heat loss and solar gain indoors, directly associated with emotional wellbeing and overall productive functioning of building occupants [25: 7158].

Daylighting takes space planning into consideration, and recognises the role played by windows and openings for interior façade design while maintaining the integrity of exterior views. Passive design of windows moderate ventilation, humidity, and acoustics, while blocking exterior noise, enhancing luminance without compromising other functions which determine human behaviour [24]. Daylighting must not overlook lighting levels such as protection from glare for visual comfort and safety design features [26].

4.1.3 Economy of Resources III: Solar Gain and Solar Shading

Solar gain is the principle of capturing heat inside buildings and interior spaces or preventing heat escape in cooler climates [27]. This is accomplished with the orientation of windows, façades, apertures, and openings towards the sun, otherwise called daylighting. Solar shading is an ergonomics strategy that work beneficially through manipulating nature, contributing to overall reduction of energy use and cost lowering, providing qualitative advantages of comfort and improved performance, particularly in urban, concentrated residential areas [28]. Other sustainability experts argue using case studies that solar gain be an essential pre-construction process in planning energy-efficient buildings to enable sufficient daylighting while blocking harsh light [29]. In buildings with horizonal orientation, roof skylights and clerestories located on high walls extending from rooflines, provide external zenith views and efficient solar gain, but regular maintenance of these design elements (such as cleaning) is crucial for functioning integrity.

From ergonomists' point of view, the principles of daylighting and views are relevant considerations as overheating and glare could negatively impact human performance for visual and non-visual functions. Visual comfort has direct effect on emotional states and enhances occupants' adaptability to indoor and external surroundings [30]. To respond to varying geoclimatic needs for thermal comfort, different solar gain strategies are applied. For Northern regions, large panes of south-facing glazed windows; the opposite applies in Antipodean climates in the use of north-facing window openings. The orientation of windows takes sun glare into consideration as "low-altitude morning and evening sun is commonly associated with glare", notes building performance assessor Sandy Halliday [1: 230].

The design of windows should optimise solar penetration through East-West orientation, and adjustable settings must exclude low-altitude sunlight exposure while ensuring adequate daylighting. Contrastingly, North orientation provides less glare from east and west while increasing quality of daylighting. North orientation further supplies natural cooling and enhances ambient comfort. The use of double- and triple-glazing helps maximise solar gain.

4.1.4 Economy of Resources IV: Energy Use – Electricity

Controlling usage of electrical lighting through daylighting saves tremendous energy. Electrical lighting is usually required in the early morning hours, cloudy days, dusk, and night, but proper zoning of light switches cuts electricity costs substantially, avoiding unnecessary energy consumption. Heating and ventilation costs for housing can be controlled using proven energy-efficient appliances [16: 19]. The U.S. Department of Energy [31] discuss how to increase energy efficiency of built systems and the end gains for building occupants and dwellers. This concurs with the "human factor" concept by Attaianese [25], who argues that energy consumption within indoor environment, while challenging to control, has direct effects on occupants' thermal comfort, psychological satisfaction, performance, and overall health and wellbeing.

4.1.5 Economy of Resources V: Ventilation – Heat and Air Flows

Passive ventilation principles show the benefits of airflow through openings such as windows, air vents and chimneys in saving energy costs for artificial heating or cooling. Nevertheless, safety issues must be a serious consideration in ventilation for energy-efficient buildings, for instance, in designing layouts and choice of materials that help control the movement and spread of smoke and flames during fires [25]. From the ergonomics perspective, open plans and partitions made from light materials may also amplify noise transmission.

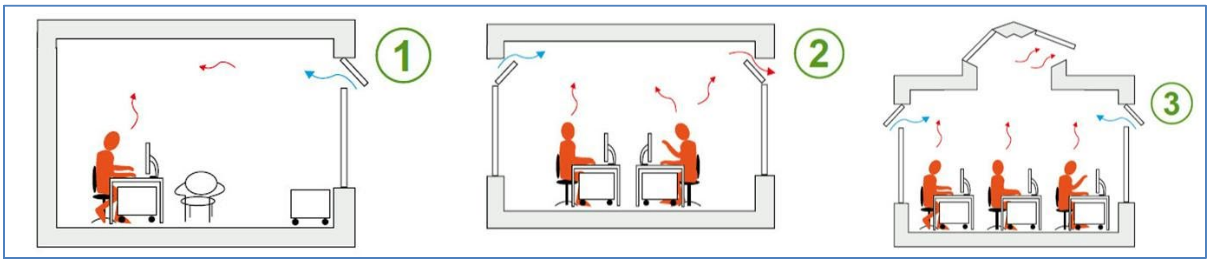

Figure 5: Types of Natural Ventilation

The system by which outdoor air is led or driven into a building using natural pressure differentials is the way the *American Society of Heating, Refrigerating and Air Conditioning Engineers* (ASHRAE) defines natural ventilation [32]. The main sustainability principles which involve wind-driven natural ventilation for cooling buildings and improving indoor air quality include (1) *single sided ventilation*, (2) *cross ventilation* and (3) *stack ventilation* (Figure 5). Insulation of the indoors is a holistic process comprising the assessment of geoclimatic contexts (such as buoyancy of wind, noise, site pollution factors, etc.) and designing solutions that optimises ventilation with proper control of interior humidity and moisture [33].

4.1.6 Economy of Resources VI: Ventilation – Thermal Mass and Insulation

Thermal mass applies the characteristics and capacities of dense materials. The function of thermal mass is based on climate, but its main goal is to strategically transfer heat or insulate from lower temperatures by collecting heat into interior spaces [27]. Construction materials that create thermal mass include thick masonry, brickwork, concrete, and ceramic tiles. Heat moderation involve insulating external walls, flooring, and roof, while thermal mass integrates with passive solar gain system in storing heat. Thermal insulation ranges from insulating pipework and hot water storage tank. Dense materials such as sheep's wool, mineral wool, and cellulose fibres, are being researched for their effectiveness in preventing heat loss through studying their ability to maintain thermal conductivity over a period of time [34].

4.2 Lifecycle Design

Material circularity affects climate change, waste, pollution, and conservation of resources. The aim of lifecycle design as a sustainability strategy is to lighten environmental impact through the design, choice, and application of energy-efficiency principles in construction [35]. Besides, lifecycle of buildings should be studied in all stages of construction from location choice to structural design, material selection for furnishing, maintenance, demolition, and the reuse-regain-recycle system of waste disposal. Sustainability architecture thus questions every process in a project's lifecycle design.

Reducing environmental impact begins with greener options of primary materials, packaging, transportation, etc. The use of less-polluting, less waste-generating materials begins with the avoidance of unrecyclable materials such as polystyrene and non-biodegradable plastics. Aside from reduce, reuse optimises energy efficiency using a "whole-house systems approach" as a key aspect of sustainable design [36]. *American Society of Interior Designers* (ASID) past president Penny Bonda and Katie Sosnowchik [37] espouses application of this "Think Conservation" system to the entire lifecycle design of buildings.

Reuse prevents resource waste: reclaimed materials can be reused in construction or teardowns, reducing raw resources. Demolition processes should be reviewed for material reuse: bricks, doors and cabinetry may be disassembled and recyclable for new projects as feedstock, or otherwise sent for reprocessing and disposal to reduce toxic heavy metal, rather than immediately landfilled, or incinerated [37: 112].

Recycling, the final operation, requires knowledge of material reprocessing into new form. Recycle is less effective than reuse due to energy consumption during transportation and the building lifecycle. Architects should commit to preferring recyclable materials during pre-planning process, glass, plastic, fabric ceiling, rubber flooring, glass, ceramic tiles, etc. [21]. Single-use material is easier to separate for recycle compared to mixed materials. Using materials efficiently by constructed with plywood or exposed bricks maintains aesthetic value and avoids harmful finishes containing *volatile organic compounds* (VOC) found in common paints or varnishing. Finished surfaces are not permitted to undergo recycling, under guidelines by UK non-profit *Waste Resources Action Programme* (WRAP).

4.3 Humane Design

Ergonomics research promote the concept of humane design as a *lifestyle* option, whereby energy use and eco-minimalism principles are defined choices determining adaptation to the natural environment. Spaces in modern homes, kitchens, bedrooms, and bathrooms, are symbolic characteristics of human-centred design planning which are practicable, as behavioural factors determine planning of spatial efficiency, safety, and optimum performance [38].

Architectural engineering Prof Buthayna Eilouti [39] citing Remijn [8], Pheasant and Haslegrave [5], states that early planning stages of architectural design should incorporate ergonomics as a holistic approach to address human-spatial interaction issues. Aside from gaining input from observation of end-user interactions and generating data from qualitative analysis of the experiences of users with spaces, interfaces and built elements, Eilouti [39] discusses human-centred design aspects from a humane aspect through understanding a building's responsiveness through its *functionality*, *flexibility*, or *efficiency*.

An example of humane design in action is by Loo, Lau, and Chee [40], who studied the way to harness tropical climate conditions to increase indoor thermal comfort of a Taoist academic centre in Kuala Lumpur, Malaysia. Adapting an inverted spatial design model using vernacular architectural elements from Malay *kampung* (rural) houses, they proposed a solar rooftop for the centre; second-floor terrace or "eco-pavilions" for public assembly function such as class teaching; and enclosed meditation rooms on the ground floor, besides exploring passive ventilation typology such as converting a deserted pool into a landscaped reflective pool to cool daytime temperatures outdoors; green façades of water curtains and trees to offer visual comfort which facilitate social interaction and reduce isolation among users.

Another humane design factor is occupant comfort from their "preferred exposure to external elements" [41], correlated to the orientation of windows to surroundings. Function necessitates proper location and placement of windows to firstly ensure users' eye-level visibility. Qualitative studies of user experience among twenty occupants of multi-dwelling buildings in Sweden conducted by Gerhardsson and Laike [41] found that inhabitants perceive themselves as being *in control* of comfort through windows. For multi-housing (e.g., apartment) occupants, windows are an important sensorial factor for home enjoyment, enabling visual tasks, reducing electricity, ensuring visual privacy, determining moods, attaining external information, forging social connections, removing unpleasant or intrusive externalities such as air movement, light, and noises (Figure 6).

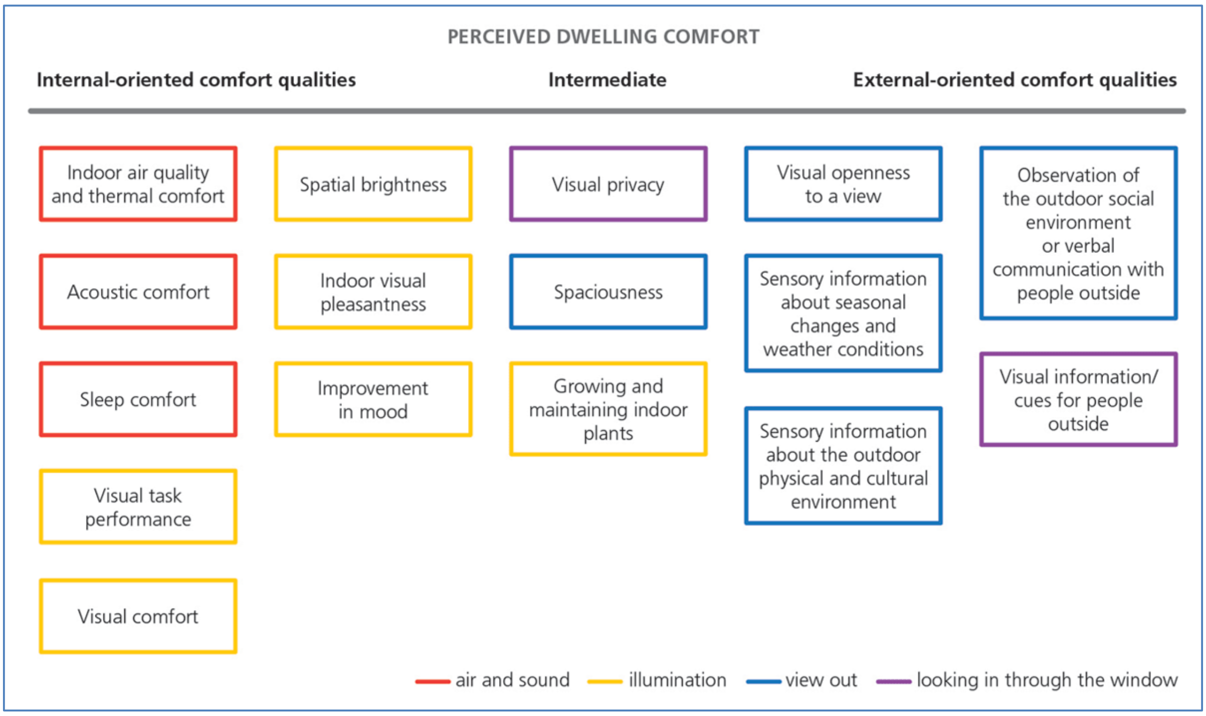

Figure 6: Perceptions of Windows

5.0 CONCLUSION

Sustainable design comes from empathy for natural systems and human ability combined, as demonstrated by The Courtyard House. The case example shows effective ways to minimise energy consumption by employing creative, simple, and elegant passive design strategies like solar gain and shading, thermal mass insulation, and natural ventilation methods.

Other passive forms like the use of vertical open spaces enhances airflow and provide ideal comfort conditions to improve occupant functioning and adaptation to surroundings. Sustainability literature reviewed in this paper clearly points to critical environmental issues which pressure and threaten human health and future resource conservation.

Architects, builders, and design researchers must have passion accompanying action to address environmental impacts, large and small, albeit to improve awareness about serious climate change and diminishing resources, energy consumption, waste management, water scarcity, etc. We have to accept the fact that population growth has scaled the negative ecological impacts and affects communities, both urban and rural. Increasing urbanisation focuses on human behaviour for human-centred architectural solutions and foretells the potential social advancements possible through building sustainable urban environments.

The critical challenge is raising collective awareness to understand the fundamental elements of sustainability and to provide clear guidelines and actionable strategies to live within parameters of comfort and enjoyment, acknowledging construction materiality, circularity of design lifecycle, various humane design factors of cultural, geoclimatic conditions and spatial needs differences of occupants, while arresting ecological degradation. Accomplishing true sustainability, to paraphrase biomimicry scholar Janine Benyus, is to prioritise "the continuation of life while reimagining the world", while reweaving the core elements distinguishable as humanity's collective vision. Future sustainable design will need to develop current architectural heritage in fulfilling contemporary living needs without compromising resource preservation.

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Figure 1: *Conceptual Framework for Sustainable Design in Architecture*. In J. J. Kim, and B. Rigdon, Introduction to Sustainable Design. Ann Arbor, MI: University of Michigan, 1998.

Figure 2: *Plan of The Courtyard House*, 2007. [Online]. Available: http://3.bp.blogspot.com/-wcfwCCvp8PM/VPDUVBAo4FI/AAAAAAAAIx0/hcHelFrdm9w/s1600/image09.jpg

Figure 3: *Bifold glass walls*. [Online]. Available: http://2.bp.blogspot.com/-AySeade-sog/VPDUUDI9WgI/AAAAAAAAIxc/Tk48asb6mPw/s1600/image05.jpg

Figure 4: *Interior surfaces*. [Online]. Available: http://1.bp.blogspot.com/-SrQehVvaWr0/VPDUTwPDbUI/AAAAAAAAIxU/QQ3Boq0wXF4/s1600/image04.jpg

Figure 5: Bronze Craft Corporation, Types of Natural Ventilation, n.d. [Online]. Available: https://bronzecraft.com/types-of-natural-ventilation/

Figure 6: *Perceptions of Windows*. In Gerhardsson, in K. M. Gerhardsson and T. Laike, "Windows: A Study of Residents' Perceptions and Uses in Sweden", in Buildings and Cities, vol.2, no.1, pp.467-486, 2021. [Online]. Available: https://journal-buildingscities.org/articles/10.5334/bc.120/