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TECHNICAL ARTICLE

Spatial Delight and Environmental Performance of Modernist Architecture in London – Golden Lane Estate

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This paper investigated the spatial delight and environmental performance of the open spaces and two selected apartments in the modernist buildings at Golden Lane Estate built after the 2nd World War, between 1952 and 1961. This estate is a Grade II listed, high density, low cost housing complex designed by three young architects: *Peter Chamberlin, Geoffrey Powell and Christof Bon*. It was built over a bombed site and well embraced the post-war modern architecture ethos, environmental considerations and inclusion of social facilities and landscaped communal spaces. Selected communal open spaces and two apartments in different building blocks with similar attributes were chosen for this study. However, one apartment has been refurbished with internal insulation and secondary glazing for improving the comfort conditions. Through fieldwork, which included subjective observation of the spatial quality of both outdoor and indoor spaces, on-site monitoring and interview of the building occupants, first-hand information on the environmental and comfort conditions inside the apartments were obtained. Through performance based theoretical analysis, archival research and observations, the spatial quality and comfort conditions in the apartments and their energy demand were critically assessed. The research findings indicate that the design of the communal outdoor spaces in the Golden Lane Estate were well thought through and the spacing between the building blocks responded well to the requirements of spatial delight, solar and daylight access and outdoor environmental comfort. Through selective enhancement of the thermal property of the building envelope, the original naturally ventilated and well day-lit living environments were maintained while energy demand was reduced by 30%, and the overall comfort level was significantly improved. This paper presents the feasible strategies to tackle the environmental challenges in the post-war Grade II listed residential buildings in the UK.

Keywords: Modernist Architecture; Environmental Performance; Spatial Delight; Selective Environmental Interventions; Occupants' Comfort

1. Introduction

Revisiting iconic examples of Modernist architecture, which have influenced and continue to influence the architecture of many European cities, is particularly important nowadays in light of the continuous strive towards better and more sustainable buildings globally. British Modernism (Powers, 2017) is well represented in London through many examples of public buildings and residential developments which provide a unique type of naturally ventilated buildings where inhabitants still enjoy considerable spatial and environmental quality. This is especially the case for the Golden Lane Estate located in the City of London designed by Chamberlin, Powell and Bon (CP&B) in the 1950s (Harwood, 2011). The significance of studying the architectural quality and environmental performance of this complex is to decode the implicit and explicit spatial design ideas and environmental design agenda embedded in the work of influential architects such as CP&B, who had produced ground breaking and influential architectural projects that responded well to the needs of a changing society in post WWII Britain, and adopted effective environmental design strategies to offer spatial drama and environmental comfort to the occupants. This gives us the opportunity to show that even without sophisticated digital quantification tools by then, CP&B were able to design open spaces and buildings which offered environmental delight and robust performance that enhanced the architectural quality of both outdoor and indoor spaces, and in this sense, these architects could be considered as the forerunners of sustainable building design. With so much emphasis and debate on the sustainable retrofit of existing buildings and in a world of diminishing energy resources and climatic change, it is important to understand the level of satisfaction of the current occupants in terms of environmental comfort and interaction with the building/s, and the potential architectural interventions made at their

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living environments in the context of the past, present and future environmental and life-style evolution of the Estate.

This estate is a Grade II listed, high density, low cost housing complex built over a heavily bombed site during WWII, and it was one of CP&B's key competition winning schemes which well embraced the post-war modernist architecture ethos, environmental concerns and inclusion of social facilities and landscaped communal spaces. It was built at a time when the local authorities, through a comprehensive recovery and re-building strategy, provided housing for single people and couples rather than large families. It marked the major commitment of British Government in providing social and affordable council housing that responded to new aspirations of post-war Britain and Europe to improve the living conditions of working people.

1.1. Research Methodology

This paper explores both spatial delight and environmental performance of the outdoor spaces and selected apartments in the modernist buildings at the Golden Lane Estate (**Figure 1**). The study of spatial delight is a key innovative characteristic of this study and the research method adopted is a combination of qualitative and quantitative analysis. The personal subjective experiences of both outdoor and indoor spaces supported by sketches and on-site photographic recording contribute to the understanding of spatial delight and the quantifiable analogue and digital performative analysis substantiate the qualitative observations.

Two two-bed apartments (**Figure 1**, blocks number 5 and 7) in different building blocks on the estate with the same orientation, internal layout, use of materials and building elements were selected for this study. The environmental performance of the chosen apartments with a split-level internal layout (one in Bayer House and the other one in Basterfield House), different ventilation strategies, internal insulation, selective secondary glazing to windows (except the front movable glazed sliding doors) were analysed. In addition, this study also aimed to explore how life style and behavioural changes have impacted on the use of the domestic spaces and the demands on environmental comfort through sensible building modifications by the building occupants.

The research started with a discussion on the historical climatic context of London and this was related to the architects' environmental design considerations of the Estate as a whole and of the two residence blocks during the design development. This was supported by further historical and archival research which evidenced the architect's response to emergent environmental requirements embedded in the early planning regulations of 1940s. The site analysis and the specific microclimate created by virtue of design in the Golden Lane Estate were analysed with a combination of fieldwork and computational modelling and simulation, examining the performance of the outdoor spaces in terms of solar access, overshadowing and wind environment. This was preceded by a climate analysis and combined with field studies of the thermo-hygrometric environment in order to predict the likely impacts on human comfort. The building massing and layout were evaluated against solar control, sun penetration and daylighting which were critical design parameters in the era when the estate was constructed. Two two-bed flats were further assessed by subjective interview, on-site monitoring and static and dynamic thermal simulation to compare the performance improvements that the selective retrofitting through internal insulation and secondary glazing had contributed to one flat against the other, which is in the most original state. This study attempts to reveal the spatial and environmental considerations applied in the design process, and also discusses the environmental benefits in terms of comfort and energy demand reduction that can be brought to the Grade II listed Estate.

2. Historical and Climatic Context

The year 2018 marks 64 years since the architects Chamberlin, Powell and Bon were first approached by the City of London Corporation to act as consultants on the reconstruction of the Golden Lane and Barbican Estates. Their Practice, also known as CP&B was founded in 1952 during a period of energetic optimism for architecture. All three architects were in their early thirties,

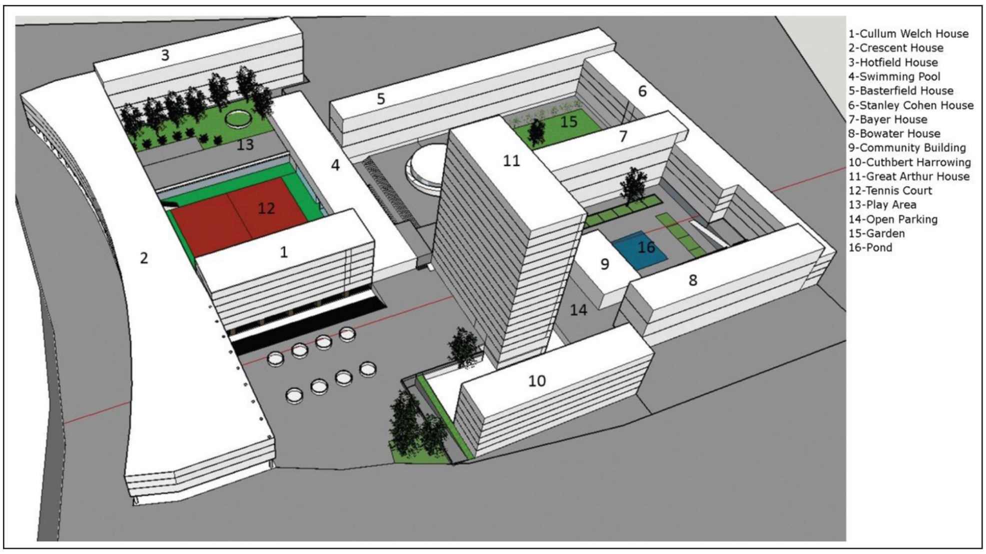

Figure 1: Overall layout of the Estate.

but they landed the ambitious commission to build what was to become a truly utopian piece of urban planning and a radical reimagining of a heavily bombed site in central London. The end of World War II in 1945 had seen a wide and heartfelt belief that there was an opportunity to build a better Britain, with greater opportunities for ordinary people than ever before.

CP&B adopted a design approach that embraced site, space and urbanism as three key elements central to architecture. One of their principal interests was the creation of places – not just buildings (Powell, 1957). This was very much apparent in the attention that went into the design of the estate as an organic and self-sufficient development which not only had a variety of communal services but also sheltered from the busy urban context emphasizing the sense of community and creating a specific microclimate, identifiable in the various courtyard created by the respective relationship of the residential and services blocks and the varying levels. The design of the Golden Lane Estate displayed strong influence from Le Corbusier, Mies van der Rohe, Frank LIoyd Wright and Ludwig Hilberseimer were other influences. When asked about their sources of design inspirations in 1989, Geoffry Powell stated that 'we were all into Le Corbusier, rather.' (Geoffry Powell in conversation, August 1989). They considered the design of a group of buildings in close proximity to each other as if they were a single problem in design, and experimented with aesthetic and composition (Penoyre, 2012). The split level spatial arrangement in the apartment blocks displays the influence from Le Courbusier's Unité d'Habitation and heroic roof structure on the Great Arthur House shows the reference to Le Corbusier's buildings in Chandigarh, India.

2.1. London in the Post-War Era

2.1.1. Planning Policy in the Post-War Era

In the middle of the nineteenth century, over 130,000 people resided in the City of London but by 1952 that number had dropped to just 5,000. Business and commerce had become the main uses of land in the City. Residents who had lost their homes as a result of World War II bombings were re-housed in areas outside the centre. The end of the war also led to a rise in national and individual expectations that standards of living should improve and that new housing should be the latest in architectural design. In 1950, 4.7 acres of land with its eastern limit on Golden Lane were compulsorily purchased by the City of London and it was proposed that this area could house nearly 1,000 people. There were further extensions to this site in 1953 and 1955.

2.1.2. The Competition

A series of architectural competitions for housing schemes gave exceptional opportunities to young architects and were a good advertisement for ambitious local authorities seeking to construct high density, low-cost modern housing. The construction of the scheme had to be economical and the minimum amount of steel was to be specified as this was an expensive and scarce material after the war.

The brief of the competition was to provide council housing for the people who worked in the city, especially key workers such as teachers, nurses and generally working-class people employed in the public sector. There was a great emphasis on the housing requirements of singles and couples rather than larger families. Therefore, studio apartments, two and three-bedroom apartments were given priority.

The other important requirement of the competition was that the apartments must have sufficient daylight and natural ventilation particularly in the living room and the bathroom, a drying room, a cupboard (similar to the Victorian pantry or larder) and a balcony sufficiently large to take a cot or pram, indicating the importance attributed to the beneficial impact of exposure to fresh air and sun for infants and young children, which was a widespread practice at the time in order to prevent and address health issues such as jaundice or other minor respiratory diseases. Each dwelling was also to have heating from a centralised system and hot water with the heating charge to be included in the rent.

The ambition was to design a high density, low-cost modern housing with shopping zones, open public spaces, landscapes and spaces for community gathering, therefore creating a self-contained community. This competition was a rare opportunity for architects in private practice at this time and attracted 177 schemes. It was won by Geoffry Powell, a lecturer in architecture at the Kingston School of Art College, in 1952 and went to became one of the most successful and well-designed housing developments in central London, not only at the time of construction but for many decades to come. **Figure 2** shows the original view of the housing scheme as entered in the 1952 competition by Powell. Based on the winning entry, Chamberlin, Powell and Bon, who had submitted separate schemes individually to increase their chances of winning, joined forces creating CP&B and developed the final built scheme.

2.1.3. The Evolution of the Design

The original design (**Figures 2** and **3**) continued to be modified during the nine years it took to construct the estate to take account of changing regulations and the expanding site. The architects felt that in the original competition scheme, the buildings were too large for the courts. This was overcome by concentrating a larger number of flats in the tower block, which eventually reached

Figure 2: Initial proposal (view) for the estate (Hardwood, 2011).

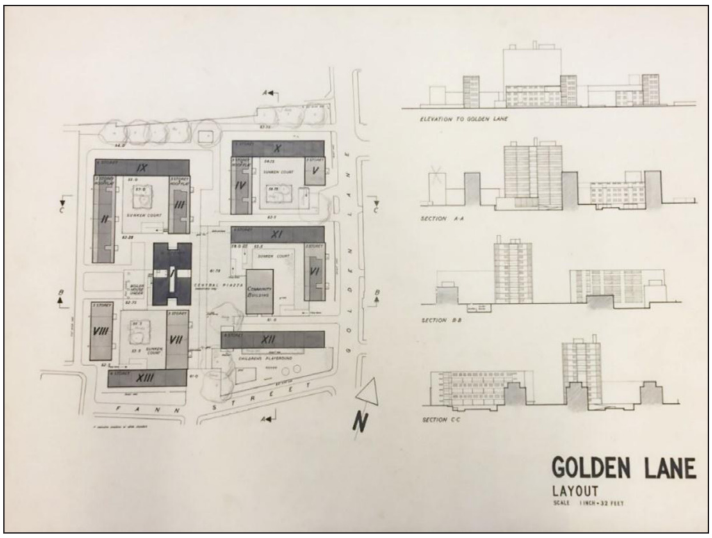

Figure 3: Original proposal with site layout and sectional elevation (Hardwood, 2011).

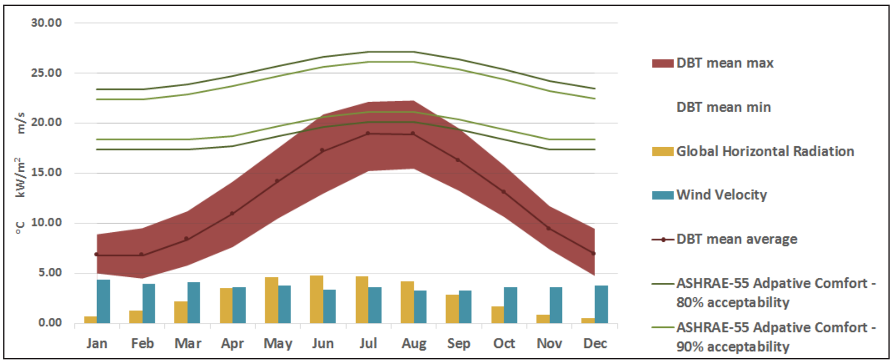

Figure 4: Monthly Avearge Climate data of London (from Meteonorm v.7.1).

16 storeys, and reducing the frontage of the maisonettes and planning the buildings on or close to the building lines.

The deep basements from the buildings formerly on the site were exploited to produce courts at the different levels, with sunken courts giving access to the service roads and stores. The varied open spaces provided the 'sympathetic environment' required inside the estate, which was conceived as enclosed and separate from adjacent sites which still suffered from damage and dereliction. The details published in 1957 show a bowling green, which was later changed to tennis courts.

The increase in the available land for the development during the project meant that all the blocks were not designed at the same time & important stylistic differences are visible between the earlier curtain walled blocks with coloured glass infill panels and the later reinforced concrete block along Goswell Road, with Cullum Welch House occupying a middle position in the stylistic development with brick and concrete construction and no coloured glass cladding.

The building form was completed in two phases. After acquiring more land in 1954, the site was expanded to 7 acres (previously 4.7 acres) expanding towards Goswell Road making the robust Crescent House the final building to be built on site. The Golden Lane Estate was to reside around 1500 people. The inward looking layout of Golden Lane has 11 built forms in total. Out of which nine are residential blocks with varying heights housing 550 units, and two are leisure centres. The other functions include shops, a pub, a community centre, swimming pool, two tennis courts, a children's nursery and recreation rooms and an underground car park.

2.2. The Climate of London

London is located at Latitude 51.5 N, Longitude 0.1 W and is at 100 m to 245 m above sea level. It is characterised by oceanic climate with a warm season from May to September with average daily temperatures between 14°C and 19°C and mean maxima above 20°C (**Figure 4**). The temperatures stay below the indoor comfort zone the rest of the year. Only occasionally there are heat waves that drive daytime temperatures above 30°C. Ice and snow are also rare.

The predominant wind direction in London is from South West (SW) to West North West (WNW), **Figure 5**. Rain is quite frequent and unpredictable. However annual rainfall is below 700 mm which is lower than in Rome and South of France.

The length of days varies significantly. In winter the day is only 8 hours. People often experience seasonal affective disorder due to lack of exposure to daylight and a sky type predominantly overcast. During daytime the low sun

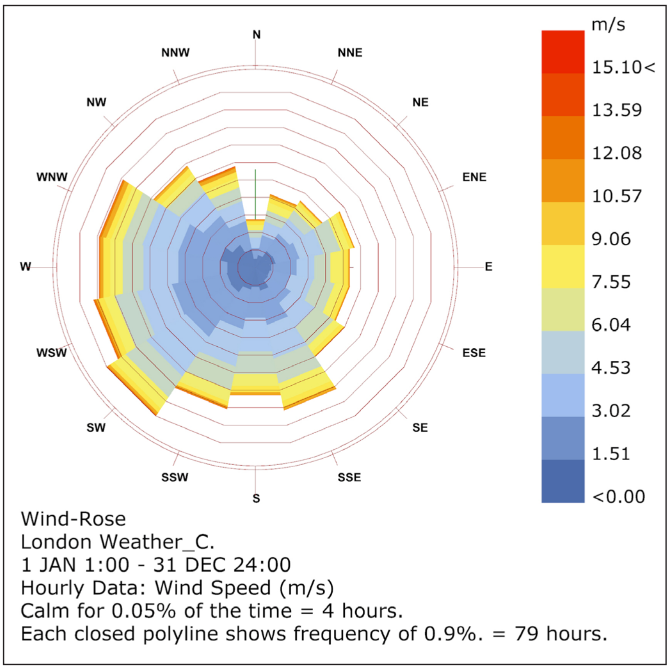

Figure 5: Annual Wind Rose Diagram for London (from Meteonorm v.7.1).

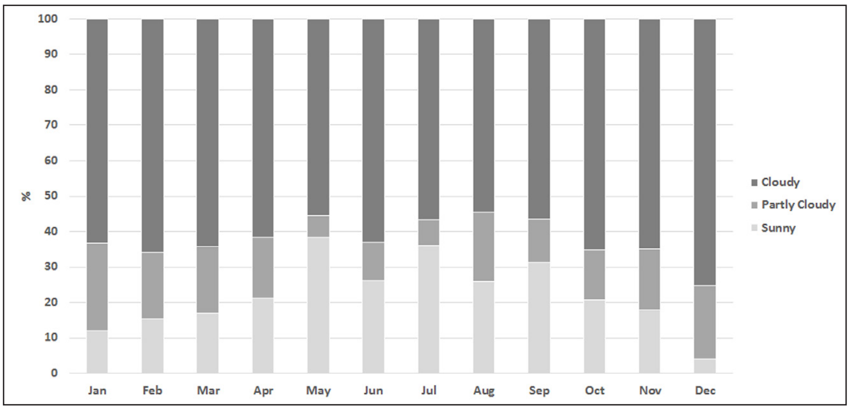

Figure 6: Monthly frequency of sky types (8 am to 6 pm) for London (from Meteonorm v.7.1).

angle is often obstructed by buildings and there is little solar access especially in urban areas. Facades on NE to NW orientation are not exposed to sunlight. In summer the days are more than 16 hours long. Common complaint in summer time is early sunrise (before 5 AM) which may disturb sleep if a bedroom window faces East. London enjoys under 1600 hours of sun out of 4400 possible (Met Office, 2016). The average outdoor illuminance varies between 50 klux and 5 klux (**Figure 6**). Average solar radiation on a horizontal surface peaks at 500 W/m^2 in July (**Figure 4**).

3. Site Strategy and Microclimate

The site strategy which included orientation, massing and land use reflected the architectural genius of CP&B and demonstrated the reasons of such a successful housing development still to this day. Golden Lane Estates combined high density housing with the exemplification of a truly modern architecture which reflects not only the concepts of modernity at the time but also responsiveness to the ever-changing lifestyle of Londoners.

The overall design of the site was expressed in a series of strategies which cumulatively created the specific character of this final complex: the layout of the buildings being perpendicular to each other in the north-south and the east-west orientation to respond to the varying needs of the inhabitants; the inclusion of courts with different surface finish carefully selected to contribute to different microclimates; the physical and visual link from the living spaces to the courts on the south side in between for the maisonettes to enhance the spatial delight; the heights of the buildings in harmony with the width of the courtyard to minimise overshadowing and maximise solar exposure where needed; the creation of gardens from the bombed areas to create a balance between the heights of the blocks eliminating extra excavation works.

Apart from the land use the estate also boasts the rich colour and use of construction methods, technologies and techniques to address the need of the inhabitants. The use of primary colour in the south facing aluminium panels on the maisonettes built in brick is in contrast to the use of monotone pick hammered concrete buildings on the east west orientation. Great Arthur House, which was the tallest building in London for several years, had a unique character that stands out from the surrounding buildings attempting to give greater hope and revitalisation to the once deserted city. The luminance analysis further supports the hypothesis that the Great Arthur House was finished in the particular yellow spandrel panels to be a glowing light and a beacon of hope to the people on the estate and beyond. With these features and given the great appreciation and satisfaction expressed by the local inhabitants, the Golden Lane Estate stands as unique site and as truly envisioned by the architects is a city within a city.

3.1. Site strategies

The Architects Chamberlin, Powel and Bon had a distinctive architectural language that was prominent in the design development of the Golden Lane estate. The trio disliked the garden city concept which results in low density. They envisioned to create a city within a city and they expressed their architectural language in the layout and aesthetics of the estate. Powel's inclination for pick hammered concrete, inspired by the mining section of 'land of Britain complex', is reflected on the finish and the building structure of the Stanley Cohen House. Chamberlin and Bon worked closely and their interest in using multi – colour so maturely applied in the residential blocks of Golden Lane Estate was also prominent in other earlier buildings such as the Bousfield Primary School in Kensington. CP&B, as explained by Harwood (2011), were among the first architects to consider three-dimensional solutions as part of their design repertoire.

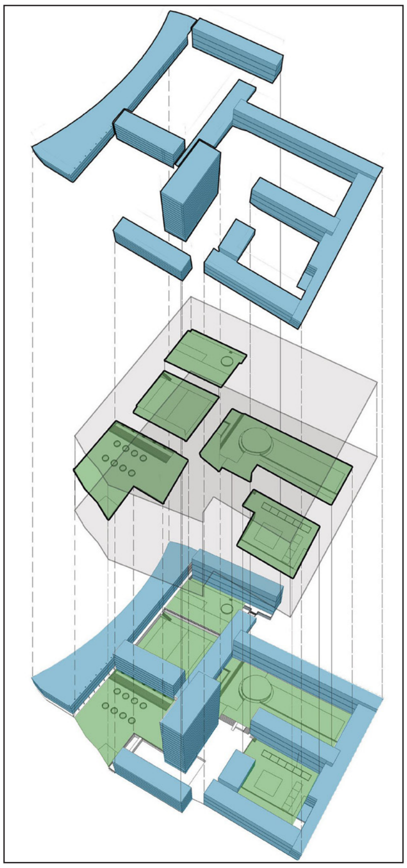

Figure 7: Spatial ratio between building blocks and open spaces.

3.1.1. Massing and layout

The concept of the 'city with in the city', was not only realised by careful design of path ways and functions to facilitate the self-contained feeling within the estate but also by creating specific microclimates within the various courtyards, which effectively modulated and contained the urban disturbances coming from the busy perimeter streets and moderated the climatic factors affecting the larger urban context. In fact, the introverted layout of the estate by which the residential blocks were designed to look into the courts and the courts in turn designed to create distinctive microclimates within the estate, contributed to this result (**Figure 7**). This introverted design and the generous proportions of the courtyards (width of the courtyards being minimum of 2 times the height of the building) provided shelter from the wind while also enabling the sun to penetrate into the foot of the buildings.

3.1.2. Orientation and typology

The Architects very much considered the impact of orientation and the specific requirements for different kind of housing. The massing was conceived so that all the buildings were laid perpendicular to each other. This results in either a north-south or east-west orientation building layout in the entire estate (**Figures 8** and **9**). There were two types of housing: maisonettes and apartments. The maisonettes were all two bedrooms and had shallow plans on the North-South orientation. These were suited as family houses and the architects possibly envisaged them for a more affluent society (Harwood, 2011). The apartments had either one or two bedroom flats and were all laid on the east-west orientation. The apartments were probably designed for people who could not afford the maisonette and who would probably move away over time. The maisonettes had a lively colourful surface treatment with the lowest floor gaining access directly into the courts while the apartments could only have the benefit of viewing the courts from inside. The maisonettes were all built as brick load bearing structure while the apartments were concrete structure with a robust finish.

3.1.3. Colour

The inclusion of colouring in the estate was an intentional attempt to revitalize the area and give bigger sense of belonging and hope to the people residing in the estate. It was with this intent that the Great Arthur House was designed to be the tallest building of that period with the first curtain wall and finished with yellow Pilkington glass (**Figure 10**). The independent buildings had primary colours which gave life to the Estate while the Great Arthur house that stood at the entrance and dominated the entire area would glow in the morning and the evening.

Apart from the obvious symbolic function of the bright beacon of hope and outlook into modernity represented by Great Arthur House, there were visual and environmental implications that the yellow reflective curtain wall

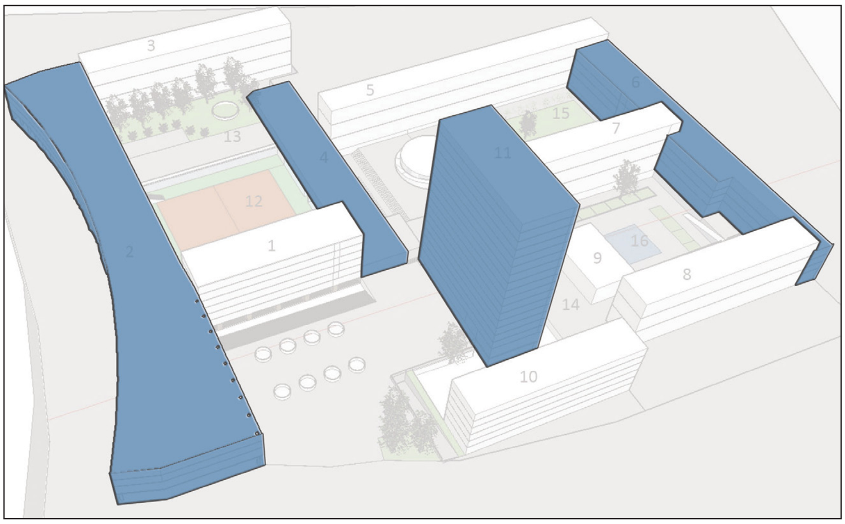

Figure 8: East-west facing blocks.

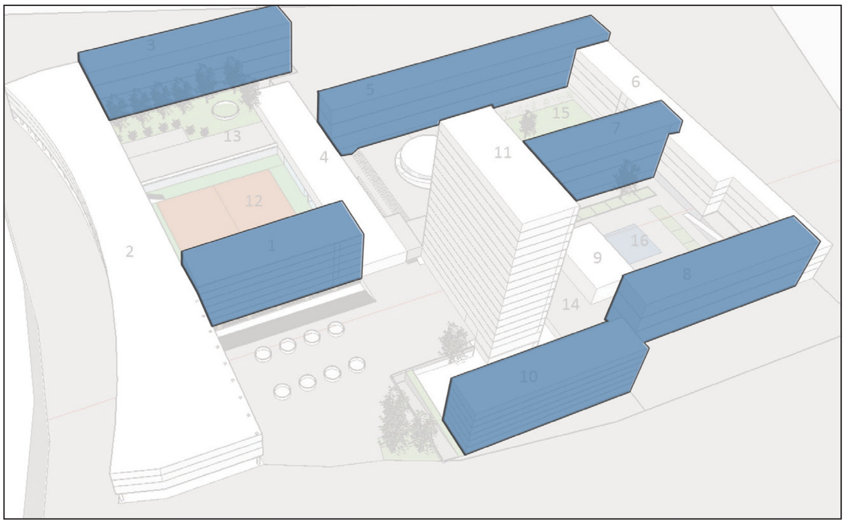

Figure 9: North-South facing blocks.

Figure 10: West elevation of Great Arthur study on Great Arthur house on east.

has on the surrounding. These are quantifiable through simulations on the luminance level of the Great Arthur House and the surrounding blocks. The luminance analysis, using DIVA in Rhino and modelling the combined yellow spandrel panel and Pilkington glass with 0.8 reflectance used for Great Arthur House, shows a high level of luminance of over 10000 cd/m^2 simulated for a typical day in July (**Figure 11**). Whereas the luminance levels of the surrounding building facades with the reflective value of 0.4 is comparatively lower.

3.2. Outdoor Environmental Performance

From an overview of the massing of Golden Lane Estate, the spatial ratio between built mass and open spaces, and of the treatment and importance given to the outdoor spaces, it is undeniable that the architects had thought very carefully about the outdoor environment in the design of the whole development. Evidence of this intention is sought through an integrated approach which combines historical evidence and evidence derived from the environmental performance analysis of the outdoor spaces in their current configuration. From an archival search into the original drawings for the competition entry by Geoffrey Powell deposited at the Corporation of London, it emerges that some level of awareness and concern for environmental site analysis was present at the time of the early design. **Figures 15** and **16** show the Daylighting Indicators used on plot boundaries and between buildings on the same plot. The Daylighting Indicators were part of the requirements for daylighting compliance set by the Corporation of London and outlined

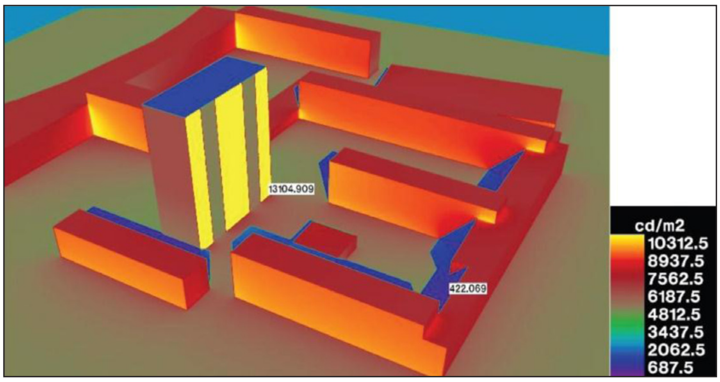

Figure 11: Luminance facade in a typical day in July.

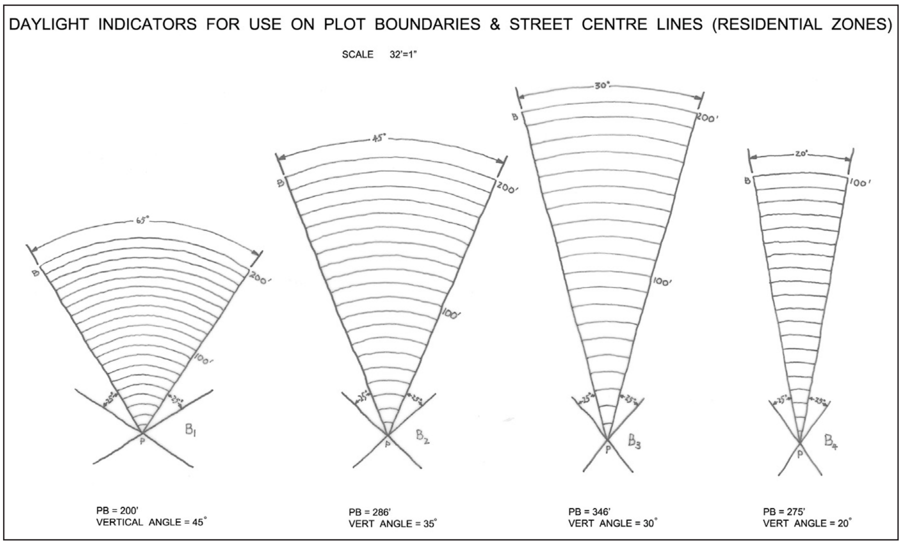

Figure 12: Daylight indicators for use on plot boundaries and street lines for residences (after Daylight Indicators plots at London Metropolitan Archive, redrawn by Yi Chen).

in the 'Lighting of Buildings' published by the Building Research Board in 1944 (Ministry of Works, 1944). However, the exemplification of the Daylighting Indicators' use and application was contained in the publication, 'The Redevelopment of Central Areas' by the Ministry of Town and Country Planning (HMSO, 1947). As exemplified in **Figure 17**, the Daylighting Indicators were printed on tracing paper at the appropriate scale and superimposed on to the plot layout drawings at the same scale in order to verify or derive the correct height and spacing of the blocks in order to maximise daylighting and solar access in the buildings.

3.2.1. Solar Access

The study of solar access and overshadowing over the Golden Lane Estate reveals the attention placed in the massing, layout and orientation of the various blocks to minimise overshadowing where necessary (e.g. playground) and allowing functions which benefit thermally and visually from some level of overshadowing (e.g. tennis courts). The presence of courtyards of various sizes and the appropriate spacing between low rise blocks arranged around them provides good solar access to most south facing aspects for most of the year (**Figures 12, 13** and **14**).

3.2.2. Solar Radiation and Sunlight hours

The radiation analysis and sunlight hours calculation show the deep penetration of the sun into the courts for most times of the year, with the longest hours of sunlight received in June and the highest amount of radiation received in September (**Figure 21**). This is possible due to the arrangement of the buildings with courts of different sizes which allow better sun penetration.

The Crescent House and the Basterfield House are the most affected despite the configuration of the buildings. The crescent house is affected due to the buildings on the other side of Goswell Road. The Basterfield House is affected due to the narrow road on its north side and the school immediately after that (**Figures 18, 19, 20** and **21**).

3.2.3. Illuminance

The massing of the building and the layout has a direct implication on the illuminance level in and around the site. This is shown by spot measurements and the calculation of the sky view factor. The onsite measurement shows the effect that the court has when the sun is lower and towards the south east horizon on the sky.

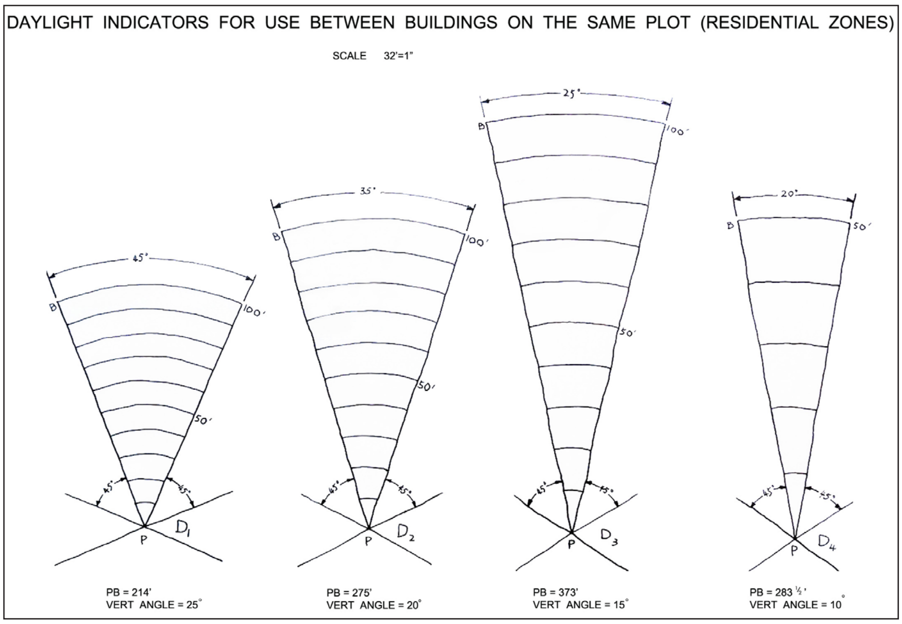

Figure 13: Daylight Indicators for use between building on the same plot for residences (after Daylight Indicators plots at London Metropolitan Archive, redrawn by Yi Chen).

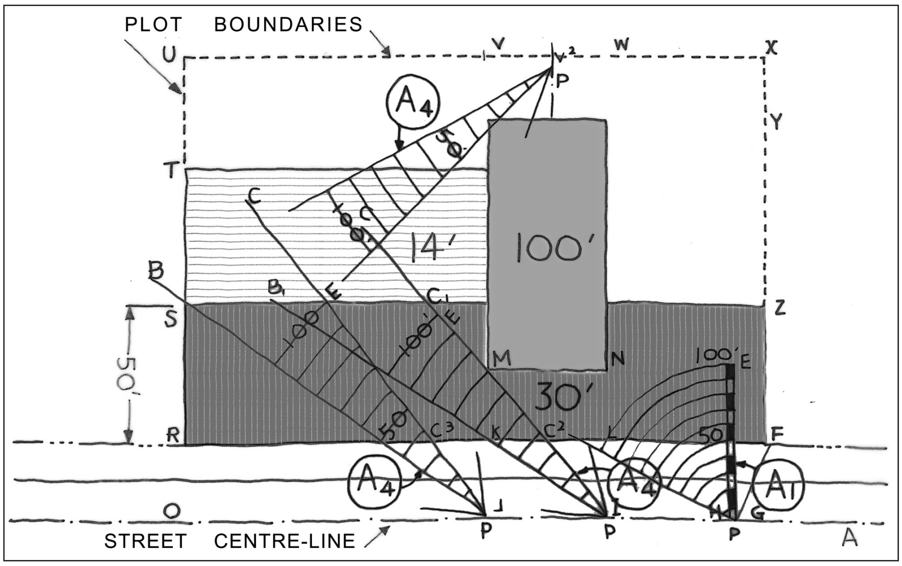

Figure 14: Daylight study applied at the estate for massing study and design development (after 'The Redevelopment of Central Areas', 1947. London Metropolitan Archive, redrawn by Yi Chen).

The initial radiation analysis suggests that the sun reaches the foot of most of the buildings for at least 9 months in a year, resulting in higher illuminance level.

An analysis of the ground finish materials and the obstruction of trees that on the site was carried out. This shows that even under direct sky the paved area has lower illuminance due to the low reflectivity of the dark coloured concrete tiles.

3.2.4. Wind and Comfort

Although in London the dominant wind directions are from South-east and North-west, wind flow in a specific urban site varies significantly from place to place and at different times of the year. Findings from site measurements show that the predominant wind direction in Golden Lane during the fieldwork campaign was south to north as measured over 5 times during subsequent visits.

From measurements taken in October 2016 during morning hours, there is initial anecdotal evidence of lower wind velocities within the Golden Lane courtyards than in its perimeter. In fact, the wind velocity was recorded at its maximum (4.6 m/s) at the entrance to the Golden Lane Estate from Goswell Street, under the pilotis of Crescent House. In contrast the wind velocity within the courtyards was recorded as ranging between 0–2 m/s, further confirming the sheltering effect of the multiple courtyard arrangement.

Further analysis of the wind environment within the site was undertaken using Computational Fluid Dynamic simulation (Autodesk, 2016). The analysis of

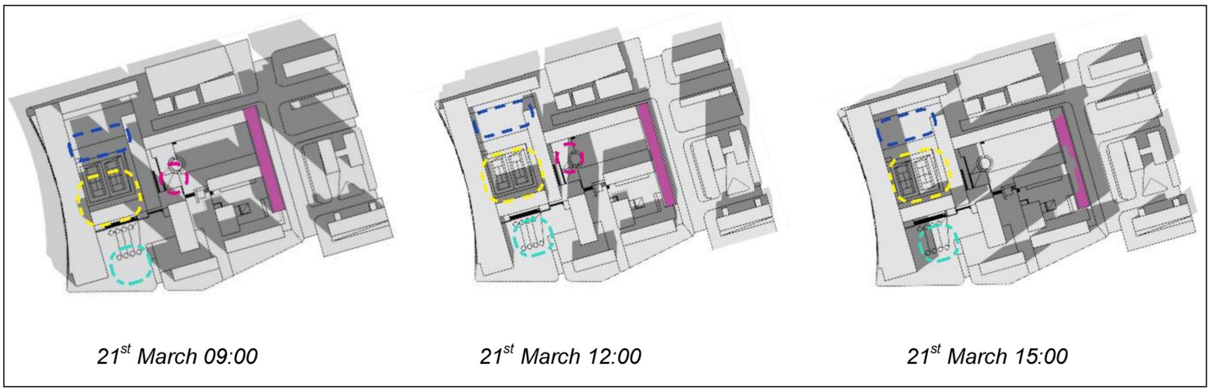

Figure 15: Solar access study during Equinox (March).

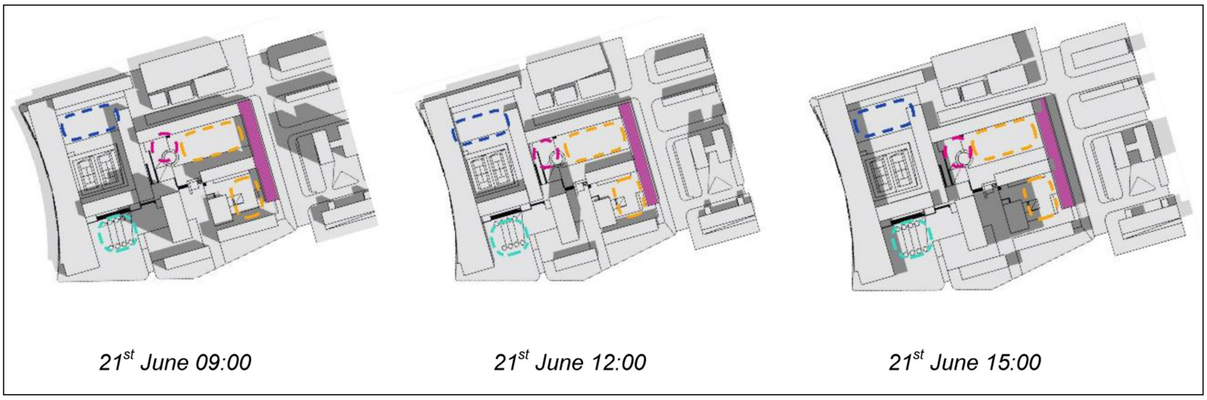

Figure 16: Solar access study in summer solstices.

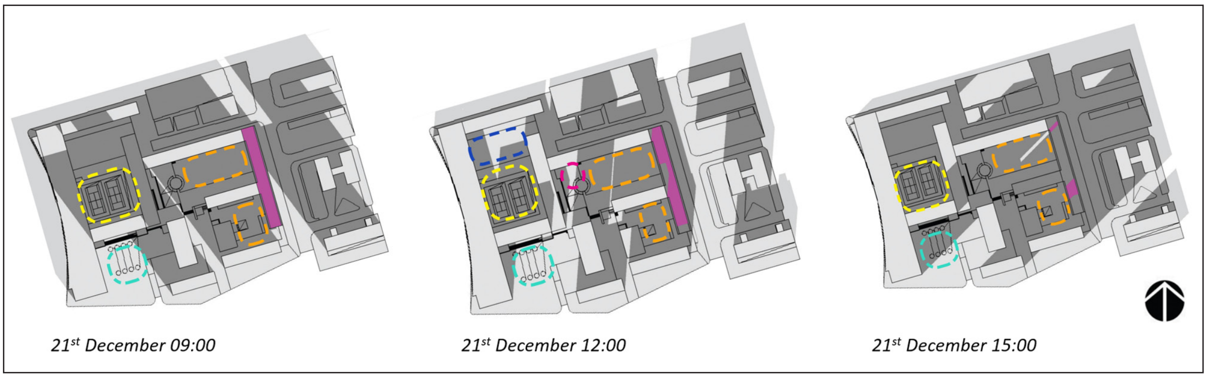

Figure 17: Solar access study in winter solstice.

the various wind speeds at different heights confirmed that the arrangement of the buildings around the courts shields them from the direct wind, thereby creating a microclimate (**Figures 22** and **23**). It is evident that as the buildings are spaced a minimum of 1.5 times their height this allows the wind to flow into the courtyard without creating turbulences.

An analysis of outdoor comfort conditions was undertaken using the Universal Thermal Comfort Index (UTCI). The analysis was based on input data derived from the spot measurements used to determine the 'thermalcomfort' and 'condition of person' on the five different courtyards (**Figure 24**).

Based on the UTCI calculations, the result showed no thermal stress in any of the courts and the comfort measured neutral on the seven–point scale. Further studies were also undertaken on the impact of different finishing materials on the thermal comfort perception in the courts. **Table 1** summarizes the results from the detailed comfort analysis for each courtyard, the same is summarised below for each courts.

Court 1 has a maximum wind velocity of 5 m/s under clear sky near the entrance area. With a similar wind movement on the entire site, the estate would be under slight cold stress and the condition of a person would be slightly cool.

Court 2, which houses a tennis court was trialled with change in flooring material to concrete tiles resulting to air temperature of 23°C. The simulation shows that the area will have higher temperature but still be under no thermal stress. The condition of person would be neutral.

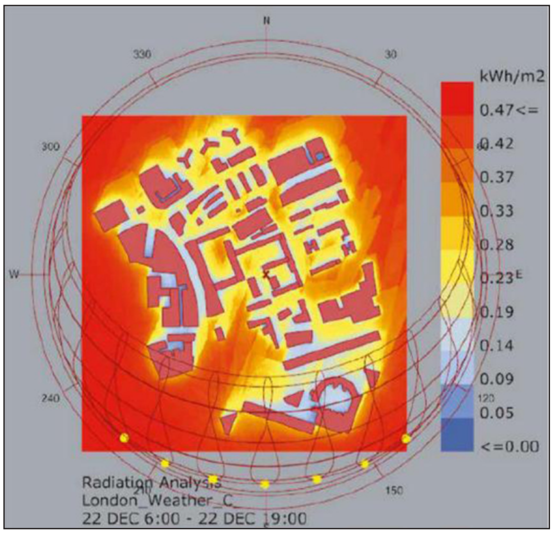

Figure 18: Solar radiation on horizontal surface during winter solstice.

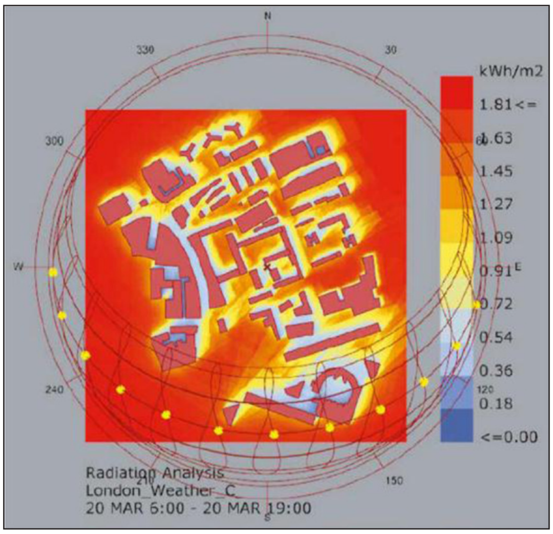

Figure 20: Solar radiation on horizontal surface during Equinox (March).

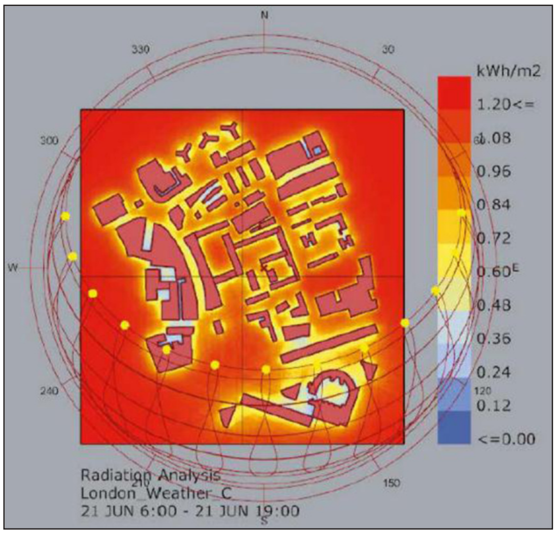

Figure 19: Solar radiation on horizontal surface during summer solstice.

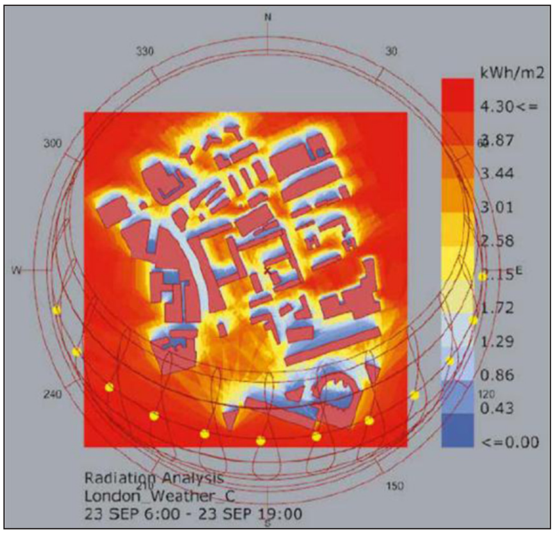

Figure 21: Solar Radiation on horizontal surface during Equinox (September).

Court 4 has a mix of water body (5%), paved areas (68%) and remaining green area with some trees on it. The flooring material was changed to complete concrete and tested for a sunny day in July (23°C). This showed moderate heat stress and slightly warm condition. This is due to the larger surface area of the courtyard and the spacing between the buildings.

Court 5 is entirely covered with grass. The flooring material was changed to 100% concrete and tested on a sunny day in July. Unlike court 4, the calculation showed slightly high temperature but no thermal stress.

4. Comparative Studies of the Selective Appartments

4.1. Spatial Delight and Environmental Strategies

Two two-bed apartments were studied and evaluated for its original architectural design intent underpinned with environmental considerations in terms of planning, spatial layout and the choice of material. The flats are similar in orientation, size, spatial planning and building elements but one is retrofitted (Basterfield House) while the other is in its closest original design stage (Bayer House).

As shown in **Figure 25**, both apartments are maisonettes with North-South orientation and a shallow plan accessed from the ground floor. The lower floor consists of living cum dining room and a kitchen. The upper floor has two bedrooms, a bathroom cum toilet and a shared balcony on the North side which also functions as fire escape route. The apartments have thick solid brick masonry walls on the North side with a balcony on the first floor while the south side has large single glazed windows (**Figure 25**). A large glazed sash door in the living room on the southern façade of the maisonette opens to a balcony facing the communal garden (**Figure 26**).

Although the flats are relatively small, the double height living space with open staircase (**Figures 26** and **27**), which punctuated the cantilevered concrete slab shared either side of the party wall between the duplex flats, and the corresponding glazed sash door to the south facing balcony overlooking a communal garden, conveys a spacious feeling

Figure 22: CFD simulation showing wind pattern.

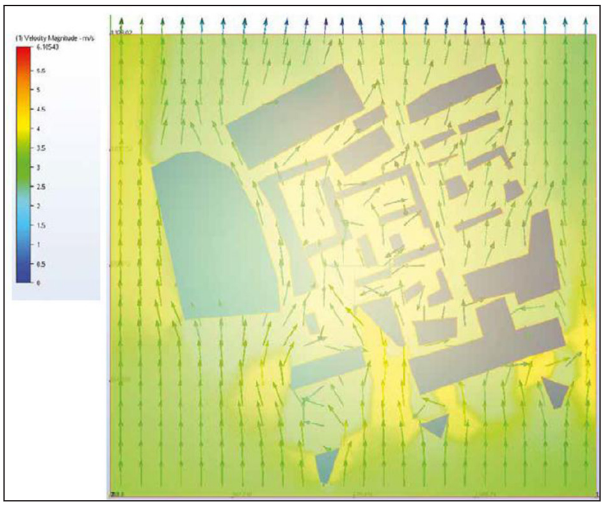

Figure 23: CFD simulation visualization of mesh of different wind velocity.

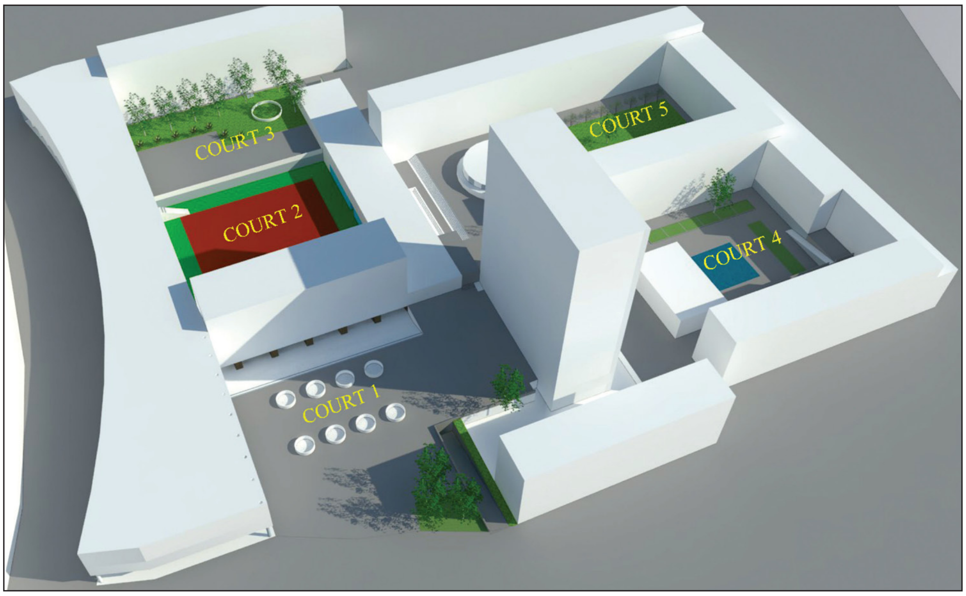

Figure 24: Simplified 3D model showing the various courts.

to the main living area. This unique design greatly enhances the openness, spatial quality, daylighting, ventilation and potential for passive heating from the South aspect.

Also, true to the competition brief, the architects delivered houses fully capable of maximising the passive potential of a shallow open plan with N-S orientation with a great opportunity for natural cross or stack ventilation. In warm summer days, the North facing kitchen window, within the 8 m deep plan, served beautifully as cool air inlet whilst the South facing outlet would draw air out either through the low level windows or, in absence of wind, through the top of the sash door, when open. On the N side wall, next to the front door and adjacent to the kitchen, an always shaded fitted cupboard replaced the function of the Victorian pantry, complete with airing brick and tick brick masonry to keep foodstuff cool and dry (**Figures 28–30**).

Another interesting detail in the upstairs North bedroom is revealed in the back single glazed aluminium frame sliding window, which extends into the adjacent balcony, creating when the door to the balcony is open, a seamless transition between indoor and outdoor (**Figure 31**).

This was clearly part of the modernist vocabulary of corner-less walls and emphasis on horizontal lines, which created an impression of continuity of space. From the environmental point of view, although this solution produced greater risk of increased infiltration and heat losses in winter, it also maximised the window opening areas for natural ventilation in summer. Additionally, the bedroom windows had a sliding shutter or curtain system, which would have provided additional opportunity for insulation and added thermal protection during winter months as well as enough space for the glazing area not to be obstructed, maximising daylighting (**Figures 32–34**). These curtains/shutters, however, have disappeared in most maisonettes following refurbishments and redecorations over the years but only the railing system at ceiling level remains to these days.

Table 1: Study on changes to UTCI in the courts with changes to material finish.

	Mean Rad. Temp. (°C)	Dry Bulb Temp. (°C)	Relative Humid. (%)	Wind (m/s)	Output (°C)	Assessment Scale	Condition of Person	Different Cases			Condition of Person	
								Extreme cases	Output (°C)	Assessment Scale		
Court 1	16	17	56	1.2	15.5	No Thermal Stress	0 (neutral)	If wind = 5 m/s	8.5	Slight Cold Stress	–1	Slightly Cool
Court 2	15	17	57	1.1	16	No Thermal Stress	0 (neutral)	If temp = 23	19	No Thermal Stress	0	Neutral
Court 3	12.5	18.5	52	2	14	No Thermal Stress	0 (neutral)	If R.H = 75%	15	No Thermal Stress	0	Neutral
Court 4	13	18	55	1.6	15	No Thermal Stress	0 (neutral)	If MRT = 25	29	Moderate Heat Stress	1	Slightly Warm
Court 5	11	15.5	61	1.8	12.5	No Thermal Stress	0 (neutral)	If MRT = 32	20	No Thermal Stress	0	Neutral

Note: According to the various spot measurements, none of the courts in the Golden Lane were under themal stress.
Court 5 case: The surface of the ground is predominantly grass. If the surface of the ground was concrete, during winter season, the area would have had slightly higher temperature but without any thermal stress.
Court 1 case: The wind velocity of the area is maximum. If there is similar wind through out the entire area, the estate would be under slight cold stress.
Court 2 case: During summer season, if the temperature rises up to 23°C, then the area will have higher temperature but no thermal stress.
Court 4 case: A small water body in a green lawn is it's characteristics. If the green lawn were to be replaced by concrete tiles then resultant condition would be under moderate heat stress.

Figure 25: View of the Bayer house facing North (left) and facing South (right).

Figure 26: Axonometric view of a typical maisonette in Bayer House.

Figure 27: Interior view of Bayer house facing south.

In winter, heating was achieved through a combination of passive solar heating during sunny days via the large south facing glazed areas, and a clever use of centralized heating which provided each maisonettes with perimeter radiators on the ground floor, whose heated convective currents were captured and transferred to the floor above via grills in the bedroom upstairs (**Figure 35**). This as well as the provision of additional shuttering system on the living room glazing demonstrated an understanding of the basic principles of heat loss and distribution by the architects. Also, the choice of concrete pre-fabricated slabs for the cantilevered stairs, allowed the thermal mass of the slabs to be heated by the solar gains coming through the double height south facing glass sash door, creating both a wonderful opportunity for the residents to sit on the stairs basking in the sun while enjoying the views of the garden and for the mass of the stairs to absorb this solar energy and release it into the room later on at night.

4.2. Performance Analysis: Bayer House and Basterfield House

4.2.1. Bayer House

An elderly couple of over 70 years of age have been living in the house for more than 20 years and developed a deep sentimental attachment to the original design. The interview findings show that the occupants are generally very happy with the thermal and visual comfort in all rooms except the bedroom on the north. The North bedroom is

Figure 28: Airing brick on exterior wall.

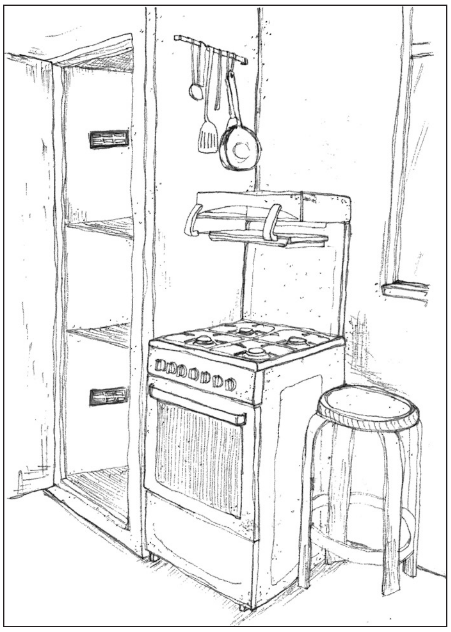

Figure 29: Sketch of kitchen interior showing the location of the Cupboard.

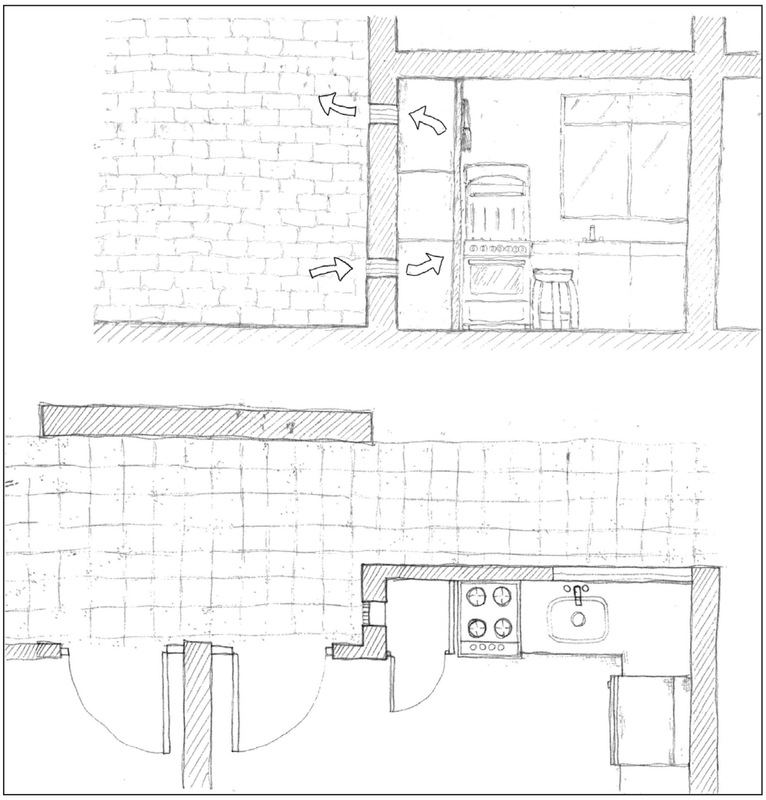

Figure 30: Sketch illustrating the working principle of the airing brick in the kitchen pantry (sketces by Yi Chen).

considerably colder than the other rooms and heating is required for most of the winter.

Figure 36 shows the overall spatial arrangement and the spot measurements that were taken during the study period in October. The total floor area of the flat is 56 m^2. The upper floor is accessed via an internal stairway. The living room and the main bedroom are located on the South side. There are large glazed areas on the south elevation (**Figure 36**). The floor projection in the bedroom to the south helps to provide shading to the glazed facade during summer as well as shelters from the rain. This also acts as a transitional space before one gets out to the open green lawn.

The overhang projection of 0.29 m has been carefully designed by the architects to allow the sun to penetrate deep into the flat during winter months. This unique façade design gives high importance to sunlight availability especially during the cold season. The Vertical Sky

Figure 31: Single glazed window in North bedroom sliding from indoor to outdoor balcony.

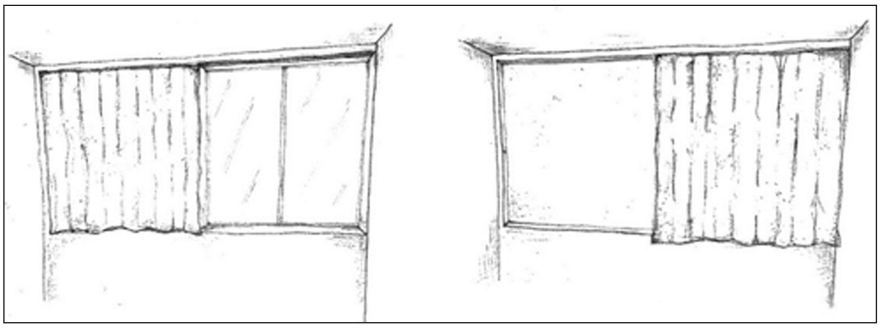

Figure 32: Sketches of the window with the original curtains (Sketches by Yi Chen).

Component measured 23° while is well within the threshold of 27° for UK for ensuring the Annual Sun Probability hours are met (BRE report: Site layout planning to daylight and Sunlight). **Table 3** shows how the slab projection serves its purpose of ensuring restricted solar ingress during summer, but deep sunlight penetration during winter when heat gain is required.

Table 2 shows the window to wall ratio in the flat. It is clear that there is a deliberate design intent to have less glazing elements in the North façade to reduce heat losses. However, the high window to wall ratio on the south elevation indicates the desire to welcome the solar gain from the south (**Figure 37**).

Table 3 summarizes the findings to demonstrate the impacts of the overhang on solar radiation with respect to the sun angles compared with the net solar gain and the transmitted radiation from the window surface. When the Sun is at its highest angle in June, it is expected that there might be chances of overheating from the large glazed elevation. However, this facade is well shielded most of the time, allowing an average transmitted radiation of only 36 kWh/m² for the entire month in June. In September when the temperature drops to about 16°C, the irradiation received by the windows averages to about 56 kWh/m². This indicates that the depth of the overhang allows more solar ingress in the colder months of the year, however, given the fewer hours of sunlight in winter (December) the irradiance received on the window surface still reaches 15.2 kWh/m².

The recommended glazing ratio for good daylighting in the UK is normally between 25–35% (BRE). In the case of the chosen flats, the high Window to Wall ratio (above 25%) ensures good daylighting for the apartments (**Table 2**), this ratio also potentially leads to extreme heat loss from the windows during winter and excessive heat gain in summer, particularly for buildings that were built in the 60s as the glazing at the time was mostly single glazed. This implies that considerable amount of heat loss from the building façade will contribute to the building heat loss coefficient of 400 W/K and 25% of the total heat loss in the building, which equates to 4000 kWh/year.

This observation highlights the need to strike the right balance between good daylighting and thermal

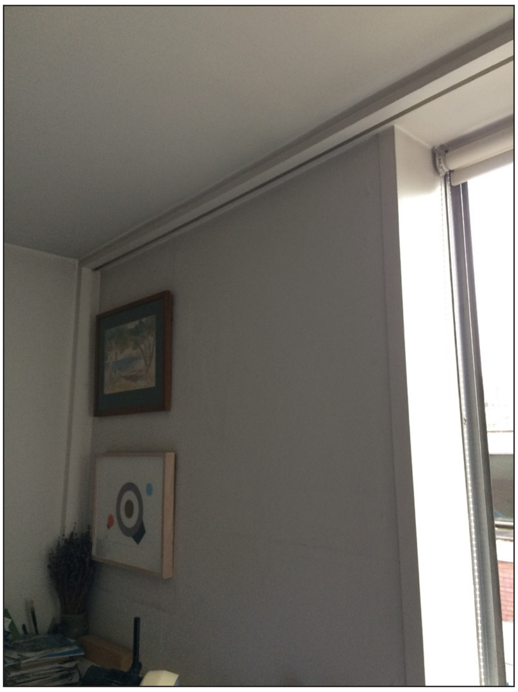

Figure 33: Interior view of the North Bedroom.

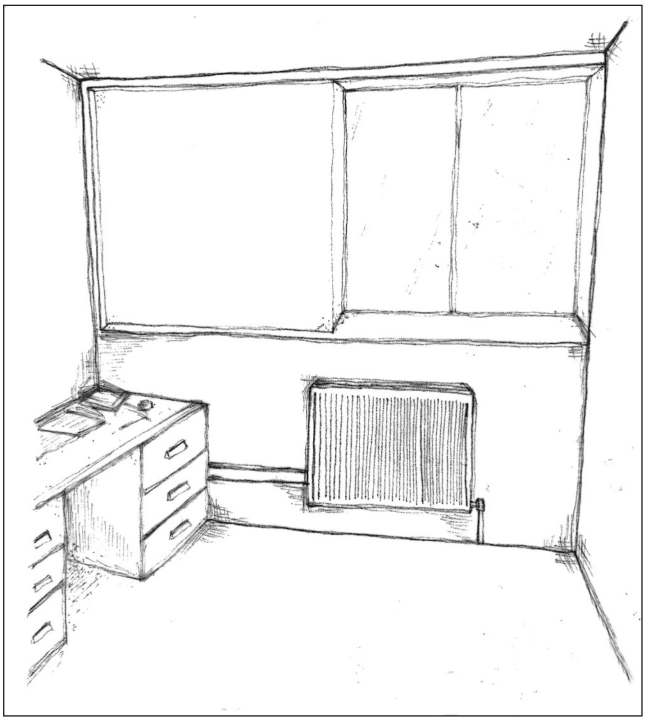

Figure 34: Sketch of the North bedroom interior.

performance so that environmental comfort can be provided throughout the year. **Figure 38** shows that the average daylight factor in the living room is about 8%, indicating a well day lit space without the need for artificial lighting for most of the time. However, the desirable daylighting performance also leads to potential heat loss by conduction through the single glazed windows with U value of 5 W/m^{2}K.

Figure 39 shows the correlated temperature profiles of all rooms within the flat in September. Apart from the data shown in the bedroom 1 which is also used as the office, the other data show a linear relationship to the temperatures at different positions within the house. The graphs also show that the worst performing room, in terms of heat retention, is bedroom 1 where a sharp increase as well as decrease in the temperature is observed, however the thick wall helps to maintain a relatively steady temperature of 17°C–18°C despite it being on the north side.

The energy index is calculated with an air temperature of 17.3°C and an infiltration rate of 0.7 air changes

Figure 35: Floor grill covering underfloor radiator (perimeter) at upper floor.

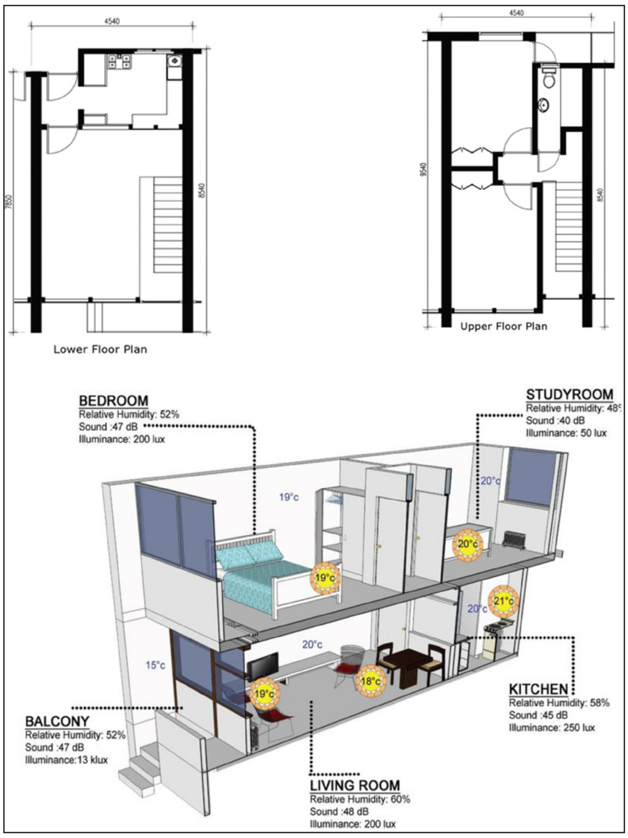

Figure 36: Floor plans and spot measurement (October).

per hour (ACH). The air temperature was derived from the findings from the data loggers by averaging the temperature of the rooms. The ACH is derived from the CIBSE guide based on the time the house was constructed and the state of the house at present.

The Gain to Loss ratio is calculated against the average temperature in London which is 12°C. A Gain to Loss ratio (GLR) of 0.502 implies that the losses are high in the house and it is primarily due to the wall with a total loss of 140 W/K. Hence the conductance of the construction material plays an important role in determining the GLR despite the huge solar gain from windows of 5697 kWh. This also indicates the need to have insulation on the building envelope.

Table 2: Window to Wall Ratio (WWR) on different orientation.

	Window area (m^2)	Wall area (m^2)	WWR (%)
South facing	12.4	20.3	61%
North facing	3.8	20.3	19%

Table 3: Result on net solar gain on south side window as a result of the overhang provision.

	Correction factor	Transmitted radiation (kWh/m^2)	Fraction unobstructed	Glass area (m^2)	Fraction retained	Net solar gain (kWh/m^2)
December	1	15.2	0.894	12.24	0.869	145
June	1	**36**	0.894	12.24	0.869	342
September	1	56	0.894	12.24	0.869	533

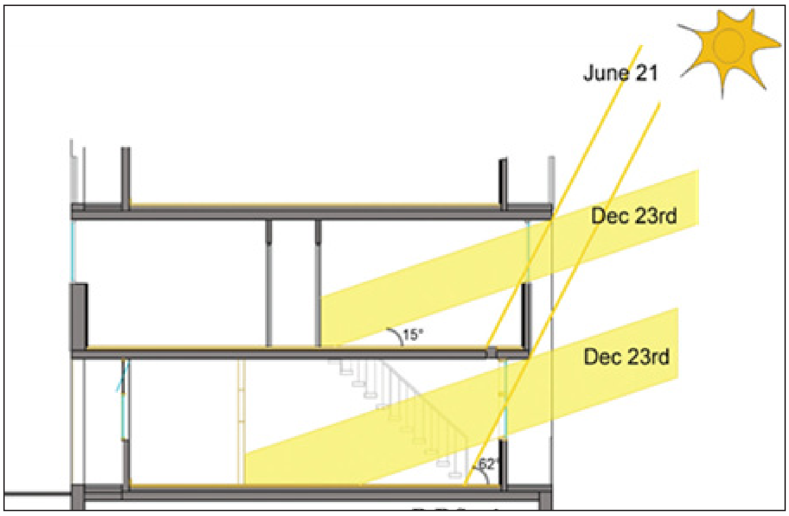

Figure 37: Ilustration of sun ingress during Summer and Winter solstice.

4.2.2. Basterfield House

Another identical apartment at Basterfield house, a replica of the flat at the Bayer house was selected for comparative studies. This flat had been retrofitted with internal wall insulation and additional secondary glazing over the existing single glazed windows. In this flat, although subjective interview with the occupants had not been carried out due to the time constraint, on-site monitoring and theoretical performance simulation were undertaken to quantify the environmental improvements the intervention has contributed to.

In 2010, the house was retrofitted and the following changes were made:

1. Secondary glazing were introduced to the existing single glazed windows with sliding arrangement on aluminium channels.
2. The walls on the ground floor and the upper floor on the south side were insulated internally.
3. The bedroom wall facing north, the kitchen and the toilet walls were also internally insulated.

There are 3 radiators in the Living room and one each in all other rooms. According to the occupant, the thermostat in the apartment is set to 21°C. Data loggers were installed in the residence to get an average indoor temperature range irrespective of the set thermostat setting. The external ambient temperature at the time of the measurement was between 3°C to 6°C in December.

Figure 40 shows that for over 80% in January 2017, the temperature profiles were within the range between 16°C to 21°C, except for some abnormalities in Bedroom south on some of the days. The south wall shows a relationship between solar gain and the loss which is dependent on the radiation falling on its surface and the outside air temperature.

The energy index is calculated on the basis of a hypothetical calculation of the total internal gains from equipment, lighting and occupancy. The equipment in place and the finding from the informal interviews is the source for the data assumed. The result shows a continuous heating of 11537 kWh per year which is equivalent

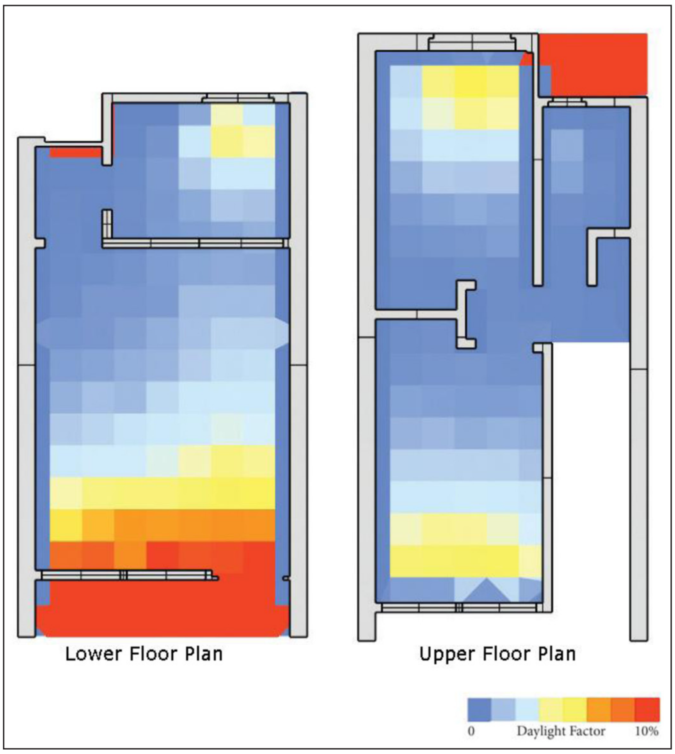

Figure 38: Daylight Factor distribution plots.

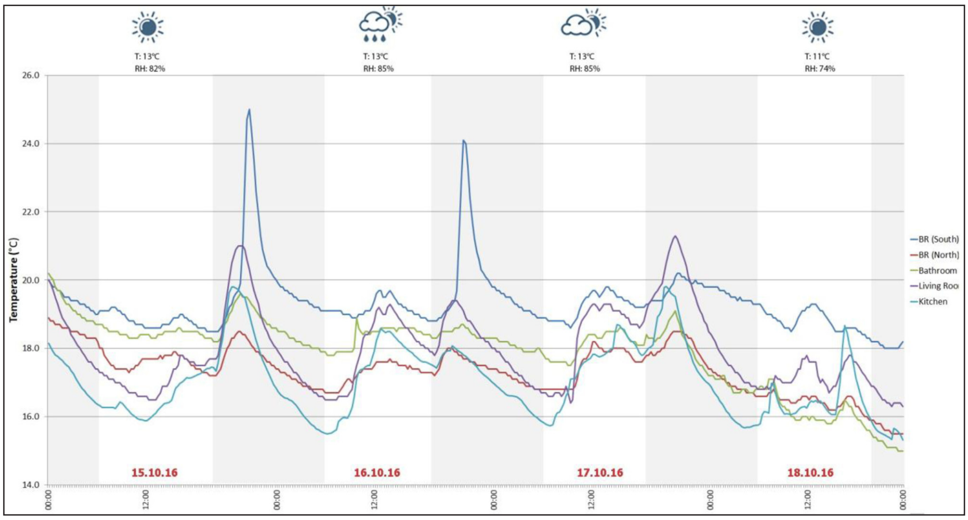

Figure 39: On-site monitoring temperature data recorded from data loggers (Apartment in the Bayer House).

to 206 kWh/m^2. This achieves D1 rating in the Building Energy Rating Standard used for domestic buildings in the UK (E2 rating is considered as the minimum energy rating required for domestic buildings in London as per Part L 1A 2016).

4.3. Comparative Analysis

A comparison of the Energy Index between Bayer House and Basterfield House shows that the overall heat loss coefficient is reduced by 20%, a clear indication that the retrofitted building envelope is a significant improvement in energy conservation. The solar gain in general is reduced by introducing the secondary glazing but it greatly helps to achieve the overall 26% reduction in heating demand annually (**Figure 41**).

Dynamic thermal simulation results show how the resultant temperature in the living room of the apartment in the Bayer House is directly related to the availability of sun and the outdoor temperature. It is a clear indication of the poor performing building fabric that contributes to high heat losses during winter. So despite having same condition for heating the room there is a difference in the indoor thermal environment. The resultant temperature in the Basterfield residence case is almost constant. This has direct implication on the heating demand, and the difference is about 30% reduction (**Figure 42**).

Figure 43 shows the relationship between the resultant temperature in the living space and the outdoor temperature and the solar gain from the windows during

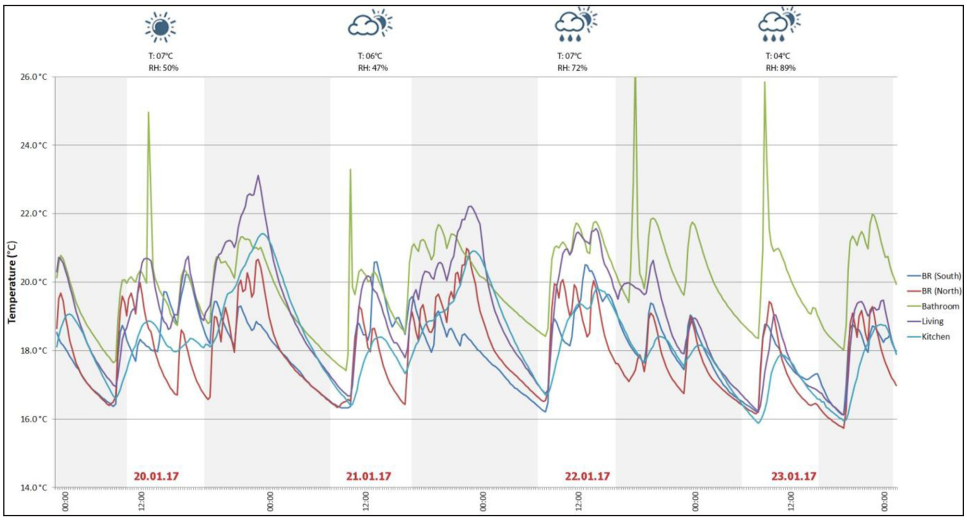

Figure 40: On-site monitoring temperature data recorded from data loggers (Apartment in the Basterfield House).

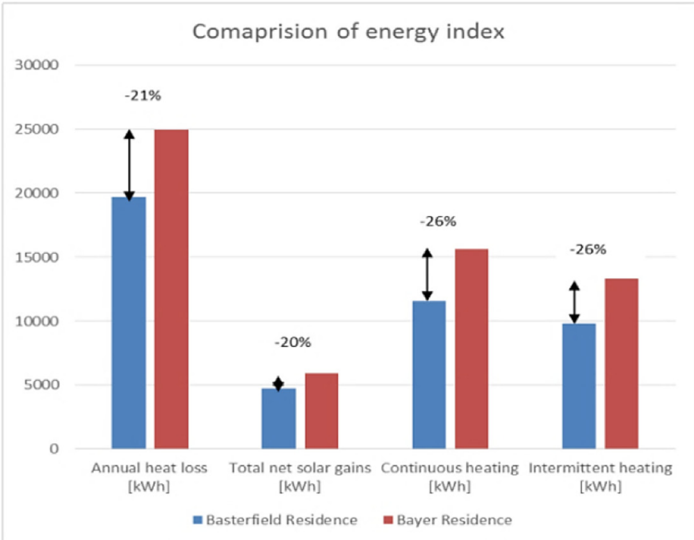

Figure 41: Comparison on Energy Index between identical apartment in Bayer house and Basterfield house.

summer. Given the retrofitting windows with low U value of 2.0 W/m²K in Basterfield residence compared to original windows at the Bayer residence (U value = 5.0 W/m²K), the indoor resultant temperatures in Basterfiled residence is much more stable than the Bayer residence on hot days. The temperature profiles on cold days (**Figure 44**) show similar constant trend but when compared against heating load, the Bayer residence requires a relatively much higher heating load throughout the year due to the poor averaged U value of 2.95 W/m²K of the original construction.

5. Conclusion

This study demonstrated the relevance and appropriateness of the environmental strategies applied to the design of the Golden Lane Estate, which exemplifies to these days timeless modernity and adaptability to the social, environmental and climatic changes occurred over the past 60 years. The concept of the 'city within the city' and the very careful design of outdoor spaces as well as of the massing, layout, orientation and material finishes contribute to a spatial and environmental delight which seamlessly transitions from the outdoor to the indoor spaces and which responds very well to the demands of an increasingly dense, noisy, polluted and overheated urban context. The field work and performative analysis of the outdoor spaces quantifies these aspects and also proves the intuitive awareness as well as the early semi-quantitative approach to solar access and daylighting design. The study also shows, through evidence from archival research, that explicit concerns with environmental design parameters were addressed in the project and that these semi-quantitative tools and techniques, which were included in the early planning regulations, substantially influenced the design of the whole development and helped achieve spatially and environmentally desirable outdoor and indoor spaces.

Outdoor solar and wind studies contributed to quantify that as buildings are spaced a minimum of 1.5 times their height, this allows the wind to flow into the courtyard without creating turbulences, and overshadowing is minimised allowing good solar access to most blocks.

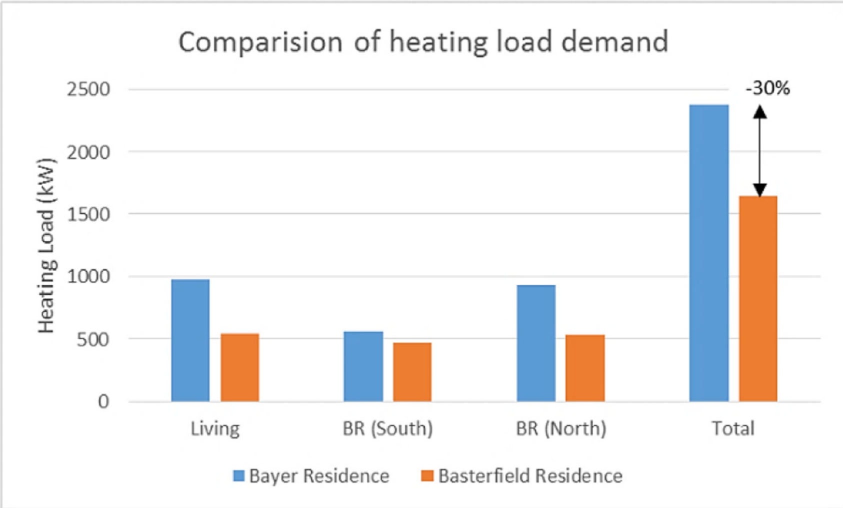

Figure 42: Comparison in heating load demand between identical apartment in Bayer house and Basterfield house.

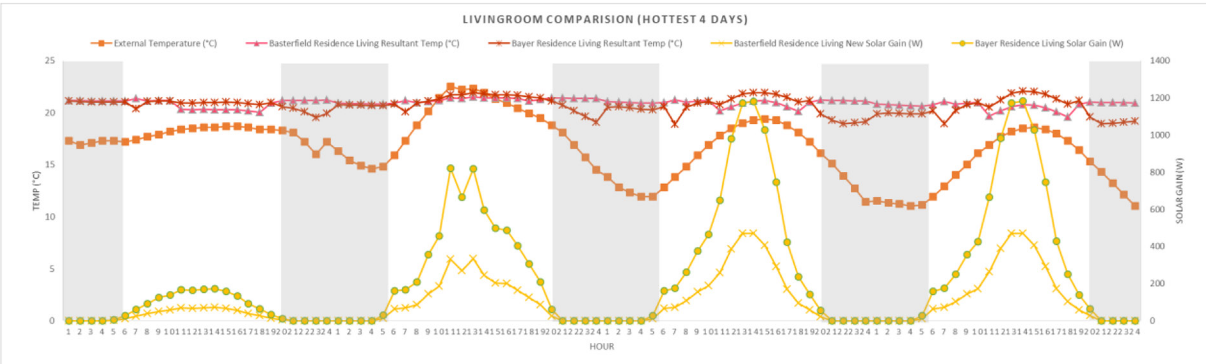

Figure 43: Comparison in Solar gain and resultant temperature during hottest days for apartment in Bayer house and Basterfield house.

This also contributes to the outdoor comfort, which in all the courtyards has been found, during the monitored typical conditions, to produce no thermal stress according to the Universal Thermal Comfort Index (UTCI). This study allowed the understanding of the impact of finishing materials on the outdoor microclimate and the appreciation of the Architect's design choices that already 60 years ago understood the importance of maintaining a comfortable and amenable outdoor conditions on the site. This emphasises the importance of not allowing material alterations or context modifications in light of the current and future exacerbating Urban Heat Island effect and climatic changes.

For the indoor spaces, the significant difference in the heating energy demand between the two chosen maisonette apartments is mainly due to the improved thermal property of the building envelope with an overall improvement in weighted average U-value of 17%. The Architects designed the building to best suit the local climate and followed the basic principles of having high glazed area on the south to receive solar gain and with minimal glazing and thick walls on the north to reduce heat loss during the cold winters. Also, the drive to maximise daylight and natural ventilation is apparent in the small details of window design and maximisation of glazed and opening areas. These currently present substantial heat losses and high infiltration due to deterioration and aging but with the advances of contemporary materials technology and specification could be substantially improved while retaining very appropriate and forward-looking strategies for climatically responsive buildings.

However, the dynamics of thermal performance work beyond the simple logical interpretation of drawing up interrelations between the intensity of the radiation and the hours of benefit. Given the low sun angles in winter, the solar radiation on a vertical surface is high (up to 2 kW at 15 hours) for the Bayer House, however owing to cold outdoor temperature, the resultant temperature in the interior is a function of the heating by the appliances in the rooms and the high glazing ratio which results in higher heat loss in cold months. The solar gain on the glazed façade is affected by the property of the glass (high transmittance for single glazing compared to low transmittance for secondary glazed) thus a difference of 750 W at 14 hours during winter months is observed.

Although theoretically the heating demand in the flat at Bayer House seems quite large, this is a subjective issue. The couple living in the flat at Bayer house practice

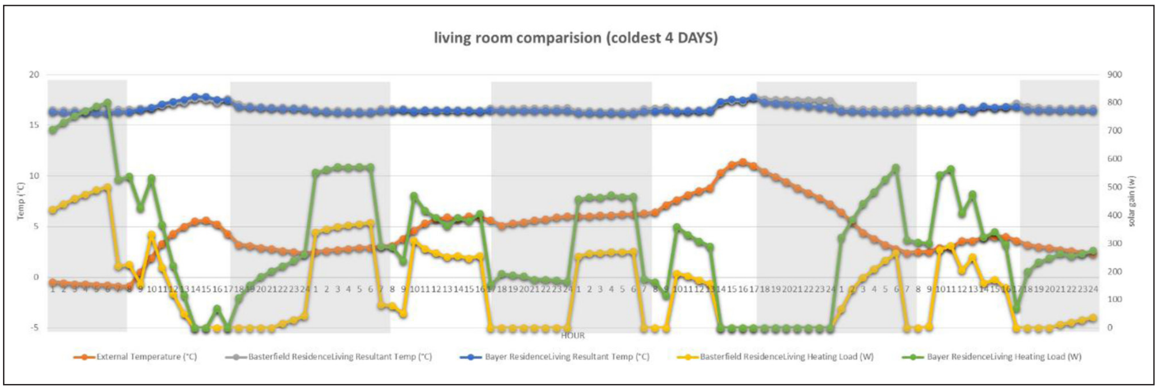

Figure 44: Comparison in Solar gain and resultant temperature during coldest days for apartment in Bayer house and Basterfield house.

adaptive comfort and put on more clothing to keep themselves warm while reducing the use of heating, their heating set point is also lower by 2% compared to the occupants at the Basterfield house apartment. As a result, life style and occupants' behaviour can make a substantial difference to the overall energy consumption.

The choice of material and its implication on the visual and the thermal comfort should not be overlooked or investigated in isolation. The visible transmittance and the G value of the glazing system have a significant role in enhancing the physical well-being of the occupants. In this case the solar gain reduction from 2 kW to 1 kW at 14 hours on a typical winter day indicates that higher internal heating demand is required while the same solar gain reduction in summer would mean that less cooling is needed.

The energy consumption in the domestic sector of UK has increased by 3.6%, with the majority being contributed by gas consumption, 5.1% higher, reflecting additional heating requirement (Department for Business, Energy and Industrial Strategy, 2016). The feasible solutions for achieving better thermal performance of existing dwellings are by reducing heat loss through uncontrolled ventilation (leaky windows and doors), improving building fabric performance with better insulation and upgrading windows with higher glazing specifications (Roberts, 2008).

Between 2014 and 2015 the consumption of energy per household has increased by 2.6%, owing to the changing expected level of comfort from individuals (Department for Business, Energy and Industrial Strategy, 2016). While accepting that life style is subject to change further, the majority of the energy conservation has to come from retrofitting the existing homes as new housing being built currently stands at less than 1% (Yorke, 2014). Therefore, it is important that existing homes are selectively retrofitted in the best way possible to ensure reaching lower energy consumption while addressing the need for environmental comfort and architectural quality.

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Competing Interests

The authors have no competing interests to declare.

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