Reverberations

Architectural Practice through the Lens of Multiscale Dynamical Fractal Systems Theory

Cliff Kerr¹ and Somwrita Sarkar²
University of Sydney, Sydney, Australia
¹cliff@thekerrlab.com, ²somwrita.sarkar@sydney.edu.au

Abstract: The postmodernist emphasis on context encourages us to pursue understandings of the communities within which buildings exist as a central component of the discourse of architectural practice. However, significant challenges to this approach exist, since the contexts in question subextend a wide range of spatial and temporal scales, and are driven by self-referential dynamical systems that are centred on the psychologies of agents who perform complementary and overlapping roles as building-dwellers and community-dwellers. This work addresses this epistemic gap by exploring the causal relations between object and context through the introduction of the concept of building-as-community. Specifically, this entails a radical rejection of the dichotomy between buildings and communities, arguing that together they form a complex system that can be explored from the ontological perspectives of dynamical systems theory and fractal geometry; the spatiotemporal patterns thus elucidated can helpfully inform aspects of architectural science. For example, the interactions within (and without) a building can be understood as a microcosm of the interactions between the building and its embedding community, suggesting a shift in emphasis towards a unified, congruous framework for understanding both buildings and communities as interrelated phenomena operating on non-coextensive but nonetheless overlapping and intertwined spatiotemporal scales.

Keywords: Dynamics; community; multiscale.

1. Introduction

To engage in a conceptualisation of architectural practice divorced of its spatial and historical context is to commit the pre-Structuralist error, first popularised by Claude Lévi-Strauss, of mistaking phenomenological content for meaning (Blackburn, 2008). The appeal of this epistemological elision is that it allows the observer to sidestep the uncertainties and complexities inherent in understanding (much less quantifying) the complex relationships between the dynamical structures that govern the relevant contexts; furthermore, it allows the observer to substitute his or her own normative discourses for those that are in fact instantiated in situ, thereby rendering the object of study more understandable (or,
perhaps, acceptable) within his or her sociocultural context and biases, even if, thus rendered, the object becomes caricatured to those who possess deeper appreciation of the context from which it was duly appropriated. An example is where a poor person’s version of community dwelling, forced by circumstances and scarcity of resources (e.g. a ‘chawl’ in Mumbai) has metamorphosed into the design typology for a rich person’s playground (e.g. a ‘café’ or ‘bar’ in Gurgaon) (Chaturvedi, 2017).

Confronted with these existential challenges to our endeavour, how can we best go about understanding ‘buildings’ in the full richness that their spatiotemporal environment demands? This is a deeply studied problem, and a plethora of approaches exist (Wells, 2007). However, a common limitation of these approaches is that they typically focus on particular aspects of the context, and thus belong to normative dialectics of their own. While ‘objective truth’ has never fully recovered from its problematisation at the hands of postmodernists, this does not mean that all viewpoints are equally valid (or, more radically, that there is not a single most valid view). Thus, although ‘absolute’ objectivism remains chimeral, it nonetheless remains possible in some circumstances to identify certain discourses as having comparatively more or less referential bias, or comparatively narrow or broad scope. While mathematics is not without its vocal critics (Burton, 1995), sufficiently broadly interpreted, it is arguably one of humanity’s most far-reaching and successful projects; its ontology is perhaps unique in being accessible across millennia, cultures, linguistic paradigms, socioeconomic strata, and gender barriers. Certainly, most if not all cultures that have codified architectural practices have adopted the ontology of mathematics with remarkable consistency. Thus, the formalism of mathematics, if used appropriately, offers a potential theoretical underpinning that is uniquely poised to be (to the extent possible) nomothetic and, contra Heidegger, orthogonal to historicity.

While ipso facto appearing to show promise, a ‘mathematical’ approach to architectural practice also includes profound challenges, both theoretical and practical. To begin with, it is not immediately obvious what this approach would even entail. Broadly speaking, traditionally there are two common approaches in which mathematical principles can be applied to (seemingly) non-mathematical subjects: as analogy and as abstraction. A famous example of the former is Jacques Lacan’s treatise relating the signifier of the phallus to the imaginary number, i.e. the square root of −1 or i. In the context of Lacanian mathematics, i is analogous to the image of the phallus:

Thus the erectile organ comes to symbolize the place of jouissance, not in itself, or even in the form of an image, but as part lacking in desired image: that is why it is equivalent to the square root of −1 of the signification produced above, of the jouissance that it restores by the coefficient of its statement to the function of the lack of signifier −1. (Lacan, 1960)

Thus, despite Lacan’s daring use of the term ‘equivalent’, within the context of the argument, Lacan is using the formalism of i to conceptualise the ‘irreducible inconceivability’ of the image of the phallus, in analogy with the irreducible inconceivability of i (Plotnitsky, 2009). Such approaches have come under intense criticism from the scientific community, partly due to the observation that by such analogies any object or concept in the world may be similar to any other, no matter how distant (Sokal and Bricmont, 1998). Similarly, the mathematical concept of ‘topology’ has been used for over 50 years as a point of departure to theorise within the architectural context about the ‘geometry of place’ (Hartoonian and Utomo, 2012): notably, the use (and usefulness) of the topological conceptualisation of architecture lies almost entirely in its ability to inspire and provoke, rather than, for example, generate equations that can literally be parameterised and solved; this ipso facto solidifies its classification as an example of mathematics-as-analogy.
While mathematics-as-analogy is principally practiced by non-mathematicians (Sokal and Bricmont, 1998), mathematics-as-abstraction typically falls within the normative discourse of mathematics itself. Mathematics-as-abstraction involves the quantification of \textit{a priori} unquantifiable subjects, thereby typically (although not always) sacrificing semantic content for computational tractability. A classic example is the computational linguistics embodied in Google’s Ngram Viewer, which provides historical analyses of word usage statistics. Only the bitterest student of literature would argue that the resultant histograms represent the most interesting or meaningful aspect of literature; yet, even these simplistic analyses have yielded some surprisingly meaningful results: in terms of global impact, perhaps the most notable of these is the discovery that Google search term frequencies are the best available predictor of flu outbreaks (Ginsberg et al., 2009).

Thus, we have two nearly orthogonal approaches, yet both of which possess a modicum of legitimacy in their claim to be a ‘mathematical’ discourse. If we may facetiously pillory mathematics-as-analogy as ‘interesting but wrong’ and mathematics-as-abstraction as ‘true but uninteresting’, a midway approach has the potential to be – one would hope – ‘interesting and true’. The crucial epistemic gap between these two constructs is as follows. Macroscopic observable facts of the ‘natural world’ can, in principle, be represented mathematically; however, the usefulness of this representation declines as the conceptual distance grows between mathematical primitives and the phenomena in question. For example, the ontological distance between the mathematical (as opposed to socio-historical) concept of ‘the square root of –1’ and Lacan’s psychosocial and ethnographic ‘image of the phallus’ is such that no presently conceivable mathematical statement could close this gap. Likewise, the phenomenological distance between statistically quantifiable word frequencies and the change in the ‘meaning’ of texts over time is also so vast as to appear unbridgeable; while the breathtaking development of convolutional neural networks and deep-belief nets has rapidly brought ever-greater semantic content within algorithmic reach – such as, most famously, unsupervised identification of the faces of cats from YouTube videos (Le et al., 2013) – such algorithms still fall well short of capturing a meaningful portion of the lived experience.

To address the unique challenges posed by the interdisciplinary nature of architectural practice, we require a middle ground between the extremes of mathematics-as-analogy and mathematics-as-abstraction. Is there a way to proceed towards the potential elucidations offered by mathematics, while avoiding the trap of pseudoscientific hyper-quantification, or, worse, becoming mired in abstruse integrals? Here we describe an approach that aims to draw on the insights offered by mathematical approaches by \textit{formulating} questions and theories in mathematical terms, while remaining cognisant of the limitations imposed by the scarce data available. This approach, which could perhaps be termed ‘mathematics-as-possibility’, in some aspects combines the ‘mathematics-as-analogy’ and ‘mathematics-as-abstraction’ approaches, while in other aspects it is unlike either; a (necessarily non-rigorous) schematic of these three approaches is given in Figure 1.

Proceeding under the assumption that mathematics-as-possibility has potential utility, the next step is to choose which aspects of mathematics to adapt for this purpose. Here we will proceed to provide an outline of one particular example of this approach – namely, exploring the implications of conceptualising buildings and communities as multiscale fractal dynamical systems – as follows. First, we provide a brief treatment of dynamical systems theory, laying the groundwork for understanding the relationships between buildings and communities as they evolve over time. Second, we introduce fractal theory, to facilitate the deconstruction of recurrent patterns that span multiple spatiotemporal scales. Finally, we propose the concept of building-as-community, which links these concepts together to unify the conceptualisation of buildings and communities within this shared framework. The framework outlined herein is necessarily tentative and speculative, and far more questions are posed than answers;
our aim is, instead, to establish a multilogue between the thinkers and theorists whose work spans from mathematics and data science through to urban and community planning, since such syntheses and integrations between disciplines are likely to be critical to the advancement of the field of architectural science over the next 50 years.

![Diagram: Conceptual correspondences between mathematical and non-mathematical discourses.]

Figure 1. Conceptual correspondences between mathematical and non-mathematical discourses.

A mathematician versed in the normative traditions of mathematics-as-abstraction will likely note the dearth of proofs, equations, and lemmata in this paper. We do not posit precise forms for the dynamical or fractal equations presented here, much less purport to solve them. Partly, this is due to a fundamental, albeit conceivably addressable, limitation: the data that would be required to constrain the parameters of such equations are not available. While architecture databases do exist, few such databases reliably record easily quantifiable data that could be used to interrogate phenomena of genuine interest to architectural theorists; for architectural science to mature as a field of inquiry, major efforts to develop such repositories will need to be undertaken over the coming decades.

Where the argument developed in this paper departs from both mathematics-as-analogy and mathematics-as-abstraction is that these approaches typically treat mathematics with considerable deference, and, more problematically, rigidity. While this is essential for mathematics-as-abstraction to succeed on its own terms, it seems equally true of mathematics-as-analogy. Even if Lacan’s use of the square root of −1 could have been equally well served by analogy with \( \aleph_0 \) (i.e., the cardinality of a countably infinite set, which also possesses ‘irreducible inconceivability’), or if Banham’s ‘topology’ could have been replaced with simpler notions from topography or geometry, such equivocations are rarely welcomed. In contrast, this paper presents concepts from two areas of mathematics, dynamical systems theory and fractal geometry, whose applicability to architectural science is predicated by the fact that they have both been successfully applied to phenomenologically proximal fields, such as urban design. Of course, this paper constitutes a preliminary and necessarily brief exploration of this topic, and we do not presuppose that these are the only, or even the most pertinent, areas of mathematics for interrogating the spatiotemporal patterns instantiated in architectural practice; rather, we state merely that they were the most self-evident due to their pre-existing discursive corpora.
2. Buildings as Evolution: Dynamical Systems Theory

One may legitimately ask what relevance dynamical systems theory has for the ‘hard and lifeless matter’ of buildings (Scribner, 1990). Yet, even buildings which remain physically static over time – and of course many do not – nonetheless evolve in context of their surroundings, as well as the people who inhabit them. Thus, one must consider the dynamicism of not just the building itself, but the reference points by which it is to be understood, and how they evolve in concert.

Certainly, one cannot expect to formulate a literal, closed-form solution of the fundamental equation of dynamical systems, i.e. \( y = \int f(t,\theta)dt \), for any nontrivial quantity of interest \( y \), where \( t \) signifies time, \( \theta \) are the parameters of the system, and \( f \) represents an arbitrary functional relationship. Furthermore, even if it were possible to formulate such an equation, it is extremely unlikely that it would be possible to obtain sufficient data to inform the parameters to solve the resultant equation, even numerically. Yet, despite the literal infinitude of possible formulae and parameterisations, particular mathematical patterns arise repeatedly in vastly disparate systems, which often allows the adoption of a general form of a problem to make the solution tractable, known as an ansatz. These ansätze can help facilitate thinking about the possible solution-space for a problem even if considerable uncertainties remain.

For example, the long-term behaviour of non-chaotic dynamical systems is typically either a stable fixed point or an oscillatory limit cycle. These dynamical primitives can be observed to reflect, respectively, irreversible changes in architectural practice and cyclic aesthetic fashions (Carbon, 2010). As an example of the latter, ornate decorative styles that were enormously popular in the 18th and 19th centuries fell out of fashion in favour of the clean utilitarian lines of modernism. However, in recent years there has been considerable backlash against these movements: the Brutalist aesthetic that was ascendant half a century ago is now considered ‘an eyesore’ (Rodrigo, 2015). The point is not, of course, that it is possible to actually formulate a quantitative differential equation to calculate the historical evolution of aesthetic preferences in architecture. Rather, it is to recognise that such a formulation would, in principle, be possible, and thus the general mathematical principles of periodic and ergodic systems apply, even if their particulars are unknown. For example, only systems with certain structures and parameters show limit cycle behaviour; however complex they may be, if aesthetic fashions can be shown to follow such cyclic behaviour, it follows that they can be expressible in this formalism. Since a system only shows periodicity when it has both a specific functional form and a specific set of parameters, such periodicity could cease with a sufficient shift in parameter values, even if the functional form remains unchanged.

As an example of this shift, consider the choice faced by architects of choosing heating via coal-burning stoves versus electric heating. Shortly after the introduction of the latter, each technology had practical advantages and disadvantages, leading to the ultimate choice in a given building being subject to the principles of aesthetic limit cycles. However, as the parameters underlying the relative costs and benefits shifted decisively in favour of electric heating, it now represents a fixed point in the vast majority of cases (subject, of course, to modification in the face of unforeseen future technological developments). In general, it is not possible or indeed necessary to quantify the functional form in order to identify what the parameters in the equation were: in this case, they were likely financial, logistical, environmental, and legislative, among others. Hence, while precise predictions are unlikely to arise from such a framework, it nonetheless informs the possible parameter space within which architectonic decisions are made. This type of approach also invites the architectural theorist to consider not merely what was and is, but, critically, what could have been: for example, a wood-burning stove in a design is a far more interesting phenomenon after the introduction of coal and (especially) electric heating than before; a choice, rather than a necessity. In mathematical terms, one would say that the system has additional free parameters.
While doing so is beyond the scope of this paper, it may even be possible to define a ‘free energy principle’ for architectural practice, in much the same way that it has been defined for other complex systems such as the human brain (Friston, 2010).

3. Buildings as Patterns: Fractality as an Organising Principle

While it is commonly believed that the fractal geometry of cities arises from their stochastic element – that is, their intrinsic rebellion against ‘the architect’s physical determinism’ (Batty and Longley, 1994) – this view is more focused on the distributed, non-centralised and stochastic spatio-temporal processes that result in the ‘fractal city’. Even at the scale of the building, though, centralised, deterministic, or non-stochastic factors can also result in fractal morphology by the designer’s explicit intention. As shown in Figure 2, buildings themselves, though (presumably) free of stochastic components, can show remarkably fractal geometry: in this case, a demonstration of the pragmatic utility of the fractal structure – namely, one that incentivises the ratio of surface area to volume. Remarkably, the pseudo-fractal designs shown in Figure 2 both predate the formal discovery of fractals by more than a decade. Mathematically, the generation of non-stochastic fractals – such as the arresting beautiful Julia sets (Douady and Hubbard, 1984) – is typically accomplished via deceptively simple recurrence relations, such as the logistic map or the closely related complex quadratic polynomial \( z_{n+1} = z^2_n + \alpha + \beta i \), where \( z \) is a complex-valued variable, \( \alpha \) and \( \beta \) are real-valued constants, and \( i \) signifies (in the non-Lacanian sense) the square root of \(-1\). Thus, principles of generative, parametric design in architecture may be said to characterise the ‘fractal’ idea, where a certain simple motif or rule is repeatedly applied to produce geometries and topologies of increasingly complex natures, possibly at several scales. Another example of such design, though not fractal, would be Stiny’s work on shape grammars (Stiny, 1980).

Figure 2. Left: Sierpinski gasket, a type of fractal. Middle: The Municipal Orphanage in Amsterdam by Aldo van Eyck (1960). Right: Robert Moses’ Stuyvesant Town, New York (1943-1947). (Sources: Wikimedia Commons (M); Jeffrey Milstean/Rex Shutterstock (R))

Stochastic and rule-based approaches for generating fractals should not be thought of as being wholly distinct: there is a tight connection between the fractal nature of a city’s network of roads and suburbs, a building’s network of corridors and rooms, and a person’s network of blood vessels and organs, as all of them are in a sense optimised (even if by unconscious and undirected causes) to facilitate the transport of entities among the nodes of the network: people and blood cells, respectively. Mathematically, this invariance is captured by a power law: \( P(x) \propto x^{-\gamma} \), where \( P \) is probability, \( x \) is a quantity, and \( \gamma \) is the
exponent. Remarkably exact scaling laws have been found for both cities and people: the exponent \( y \) has been calculated as 2.3 and 3.0 for road and vascular networks, respectively (Kalapala et al., 2006; Huo and Kassab, 2012), with the difference in the value of the exponent due to the fact that cities are approximately two-dimensional structures while humans are approximately three-dimensional (unlike Euclidean objects, fractal objects have non-integral dimensionality).

In contrast to vascular systems and transport networks, buildings often do not span the sufficiently wide range of spatial scales required in order to make quantitative statements about the dimension of their fractal geometry. However, this does not imply that the principles of fractal geometry do not apply. Qualitatively, the principles that apply on systems of scales from micrometres to metres (the human body) and on scales from hundreds of metres to hundreds of kilometres (cities and urban agglomerations) should reasonably apply to systems that exist at a mesoscale: indeed, as shown above, evidence exists that they do. Once fractality is identified as an organising principle, questions abound: in what contexts do buildings adhere to these principles, and when do they violate them? Can the fractal dimension of buildings be quantified with respect to its optimality? Is the fractality of buildings meaningfully related to the fractality of the cities in which they exist? An example of this is the case of mid-twentieth century Soviet and Chinese central planning, which resulted in fractal buildings as well as cities, but many examples in the West exist as well, such as New York City’s Stuyvesant Town – which, perhaps not coincidentally, also represents a blurring between building and community.

4. Buildings as Community: Reverberations of Multiscale Fractal Dynamics

Having laid the theoretical groundwork of both dynamical systems theory and fractal geometry, we now have the tools required to ask the central question of this paper: by integrating across both space and time, to what extent can buildings be conceptualised within the same multiscale dynamical system as the communities within which they exist? More formally, in information-theoretic terms, can we quantify the bidirectional transfer entropy between building and community?

Aside from dialectics interrogating Frank Lloyd Wright’s *Broadacre City* and Le Corbusier’s *La Ville radieuse* (Batty and Longley, 1994), surprisingly little attention has been paid to the import that urban historiography (and the hermeneutics thereof) has on architectural science. This is even more remarkable given the overlapping scales between large buildings and small communities: Geneva’s Le Lignon consists of 2780 units and houses some 6800 inhabitants, which would, remarkably, place it near the 50th percentile of ‘city’ size (Eeckhout, 2004). As a consequence of the comparative invariants of human behaviour – the tyrannical mundanities of commuting, waste production and removal, etc. – it follows that there exist significant overlaps in the challenges that are dealt with by the architects of large buildings and the planners of (or theorists of) communities, whether said communities are self-contained or constitute part of a larger urban agglomeration.

What consequences arise if buildings and communities are conceptualised not as distinct epistemic entities *qua* phenomenology, but rather as points along a continuum? This is not to deny that each has its own unique and valuable discourse. However, by considering communities and buildings as multidimensional Bayesian distributions with considerable degrees of practical and theoretical overlap, we propose that the hermeneutics of architecture and urban studies have a more substantive nexus than is commonly recognised. This statement goes beyond the truism that urban design and architecture are both buffeted by the same cultural currents. By conceptualising buildings and communities as overlapping dynamical distributions, it acknowledges the realisation that buildings and communities coextend over space, time, and most critically, inhabitants, prompting a radical rejection of their epistemic orthogonality.
This point echoes the observation by Jane Jacobs, who, more than 50 years ago, asked a similar question regarding cities themselves:

Why have cities not, long since, been identified, understood and treated as problems of organized complexity? If the people concerned with the life sciences were able to identify their difficult problems as problems of organized complexity, why have people professionally concerned with cities not identified the kind of problems they had? (Jacobs, 1961)

Buildings, too, can be understood as complex systems, regardless of whether their designers interpret them that way: yet, the field of architecture has, if anything, been even more resistant than urban studies to adopting the principles of complexity theory. One possible explanation of this conservatism is that the epistemology of a dynamical fractalist approach de-legitimises the exclusionary patriarchalism of the unquestioned dominance of Euclidean geometry:

The maintenance of patriarchal ideology sends ripples in the production of spaces, particularly in architecture and urban planning. Architecture is consummated by organizing and articulating meaningless Euclidean space to accommodate human habitation and insertion of existential meanings. Hence, architecture transcends the neutrality of geometrically determined and physically defined structure and enclosure to become a site of lived life, where cultural processes, gender transactions, and modus of sexual desire are continually enacted. (Lico, 2001)

Aside from searching more meaningfully for a theoretical epistemic connection between community and building, this framework encourages us to ask: what are the bidirectional influences and synergies between the two spheres of building and community, thereby forging them into a single ur-phenomenon, building-as-community? Even brief reflection shows that the connection is a strong one. To cite the simple example of building height – due to its straightforward quantifiability rather than its criticality to the enterprise of architecture – there exists a deep connection to city size. The Burj Khalifa would not exist in a village (notwithstanding Dubai’s remarkable transformation from being just that), and nor is a modern megalopolis devoid of skyscrapers conceivable either. The height of a building is an implicit characterisation of density, and increases in density are intrinsically linked to the growth of a city, outwards and upwards. Figure 3 plots the height of the tallest buildings over time in each of the three cities that has at one point been the largest in the world since 1880: London, New York, and Tokyo. Of these, initially London was the largest and had the tallest building; now, Tokyo holds both honours. Most of the height increases in New York City happened within 10 years of the point at which it claimed the mantle of the world’s largest city (around 1920); similarly, during the period 1960–1980, when Tokyo rapidly outgrew New York City for the first time, the height of its tallest building increased by a factor of three. Unlike the case of mid-century Soviet cities and buildings, where one could claim morphological correlation due to an external cause (the system of centralised planning) rather than direct causation (i.e., the bijective mapping between buildings and community), in this case the evidence suggests that larger cities strongly necessitate, or at minimum facilitate, taller buildings.
Surprisingly, despite the fact that cities operate on spatiotemporal scales orders of magnitude greater than buildings, the latter can often have a quantifiable impact on the former. The corollary of the example discussed above is the infamous ‘skyscraper index’, which associates the construction excessively large buildings with economic downturns. While recent evidence has challenged this correlation (Barr et al., 2015), there is nonetheless support for the view that in certain cases, if the floor space provided by large buildings is significantly larger than demand, it can negatively affect the city’s economy, as happened in Kuala Lumpur in the late 1990s following the completion of the Petronas Twin Towers (Keong, 2006). As a more positive example, Frank Gehry’s Guggenheim Museum in Bilbao provided a major economic boost, which, together with a series of additional investments, led to a major revitalisation of the entire city in the 1990s (Rodriguez and Martinez, 2003).

5. Conclusions: Theoretical Advances and Empirical Challenges

The relentless trajectory towards the mathematisation and ‘quantificationism’ of epistemic inquiry has had a chequered past, at least when such trends have extended beyond the narrow purview of the hard sciences; examples where excessive quantification has done more harm than good are not hard to find (Brown et al., 2013). Thus, one should not approach the enterprise of mathematisation lightly. While it is often considered a myth of scientism that mathematics is intrinsically more difficult than other disciplines, it is nonetheless true that mathematics typically has a high barrier to entry, especially for those unexposed to its rigidly normative discourse. Yet, mathematical approaches have often elucidated aspects of inquiry that had been resistant to traditional methodologies.

Conceptualising buildings and communities within a single unified framework – namely, as a multiscale dynamical fractal system – immediately suggests a holistic approach that has surprising similarities with Structuralist thought, despite the profoundly disparate origins of each paradigm. Namely, by dissolving...
the artificial boundaries and conflicts we construct (and perform) between the ‘architectural’ and the ‘urban’ (since, as alluded to above, the inhabitants of a city are supervenient on the inhabitants of its constituent components), we open ourselves to new possibilities in understanding architectural practice as a ‘rhythmically erotic’ choreography (Frampton, 2006), moving through both space and time, seamlessly flowing between buildings and the communities whose semiotics they profoundly, if fleetingly, reflect.

References


Identifying a Model Urban Precinct

Impact Of Built Mass for Thermally Comfortable Living in Tropics

Pabeeshani Dissanayaka¹, Malthi Rajapaksha² and Anuththara Gunasekera³
¹, ³University of Moratuwa, Katubedda, Sri Lanka
pbskal@yahoo.com, anuththarag@gmail.com
²General Sir John Kotelawala Defence University, Sri Lanka
malthidzn@gmail.com

Abstract: The Research investigates the behaviour of tropical micro-climates in urban precincts, affected by building masses; focusing in to a commercial zone in Colombo Central Business District. The tendency of growth in developing countries contributes by blocking wind path ways and cycling the solar rays of reflection resulting Urban Heat Islands. Three case study areas with similar urban microclimates and activity patterns were selected for the investigation. The building mass, aspect ratio, height / width ratio, air temperature, sky view factor (SVF), velocity of the wind and relative humidity are considered as basic attributes. Measured data were analysed by the software RayMan-Pro to provide Physiological Equivalent Temperature (PET) with a conceptual and suggestive attribute in a model urban precinct, for better thermal satisfaction levels. The qualitative changes of each precinct have been identified by onsite climate surveys; while thermal Indices behave according to Interrelationships in micro climates. The results demonstrate the urban precincts with dense building mass are having a higher air temperature levels in addition to PET behaviour, wind and shadings by SVF cannot participate positively when considered separately, but altogether make healthier micro climatic conditions with the best level of building mass composition in urban precincts in tropics.

Keywords: Urban microclimate; sky view factor; urban precincts; albedo.

1. Introduction

A comfortable healthy indoor/ outdoor environment is always being made by manipulating the built up mass to obtain a comfortable thermal situation. The construction field nowadays rapidly focus on balancing the fundamental relationship between urban massing and Thermal comfort in the built environment. Building Technologies incorporated with Architecture plays a major role in making a bioclimatic design which improves indoor as well as the outdoor environment more comfortably In Urban precincts, building is known as the primary fundamental unit of the city which contributes to a larger
impact on whole urban climate thus human behaviours of the city. Further, the atmospheric context for the building within the city includes both the natural climate and the urban effect (Mills, G., Cleugh, H., Emmanuel, R., Endlicher, W., & Errell, E. 2010). Thus the research intends to investigate the opportunities which are available for better thermally comfortable “Urban Outdoors” in warm humid climates. Within the tropics, the study zoomed in to Colombo, the capital of Sri Lanka, where a higher trend exists in changing the urban micro climate due to varying Density of the rapidly developing urban-scape; land coverage, height of Buildings, orientation and width of streets, subdivision of the building lots etc. These urban formation trends amalgamate lack of cross ventilation in outdoor micro contexts, inappropriate building forms (Chen, N. H. 2009), Reduction of convection heat removal due to the reduction of wind speed (Moonen, P., Defraeye, T., Dorer, V., Blocken, B., & Carmeliet, J. 2012) can be identified as failed interventions throughout the study area/region. Therefore it would be useful in identifying the model attributes of a thermally comfortable urban precinct in Colombo development area.

In this regards, the key factors which have been considered are building composition, aspect ratio, temperature, relative humidity, SVF | Sky View Factor and wind movement which always contribute in creating comfortable outdoor microclimate to increase user perceptions in highly urbanized areas during most effective hours of the day among a higher occupancy level.

2. Research Background

Colombo CBD, Central Business District’s population of employment during day time is 986,763 (www.statistics.gov.lk: October 2014) which have distinct relationship against climate at scales from the local to the global. This urban effect is due to the physical form of the city as a three-dimensional geometry and material composition, and its day-to-day activity patterns that generate emissions of waste heat and materials into the overlying air effects on creating the global warming crisis. Urban climate science is grappling with how climate change is likely to impact specifically on cities and their populations.

In terms of human consequences, it is the urban canopy layer that is of greatest interest and, in this regard we can differentiate between the indoor and the outdoor environments. With respect to this, the urban building physics and their thermal impact become significant with a higher balancing factor to overcome the climate issues in urban cities. The Architects’ responsibility in the building designs with respect to each impacts alluded to above can be linked to a scale of climate–built environment interaction, at which intervention will effect mostly. Sri Lanka as a tropical country has a wide range of a temperature difference. Colombo being the most affected from this phenomenon is being lead to a hot-humid city, affected by Urban Heat Island (Emmanuel 2004). As the empirical evidence suggest hard cover in Colombo increased by three and half time during last 44 years and the temperature has increased by 1°C.

The combination between human anatomy and the outside environment, directs into thermal sensation and thermal dissatisfaction of people exposed to moderate thermal environments. Creating favorable urban environments has become a huge radical challenge that needs to be faced by urban developers, climatologists and architects. In this flow, designing outdoor spaces, applying of generic attributes to the building facades preventing any detrimental doings towards global warming becomes vital.

As a hierarchical study the whole urban context can be divided in to smaller units also known as “Urban Precincts”. These urban precincts can be varied according to their building composition, Building category, system of road network and immediate vegetation. The idea of research is to understand the essential design components of an urban environment and investigate the extent of the impact of individual