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Before any detailed discussion of Ken Yeang’s architecture can take place, it is essential to understand the overall nature of his thought, philosophy, and theory of systems that underlies and structures his whole output in practice – the making of “green” buildings.

Yeang is therefore not an architect who is a maker of form alone but one who is a designer whose understanding of ecology and sustainable systems is that the reason why his forms exist, take shape and evolve are all an integral part of an ecological responsive design process. At the same time he own knowledge has greatly increased as the precision of specialist advice has improved and added to the process of his practice and research.

Two main factors characterise Yeang’s design and research as an architect, the first factor is the recognition of the existence of a relationship between the natural environment and the man made world, with the provision of low-cost energy, and supply of renewable resources that currently support the built environment as a whole. Highly important, future generations are to have appropriate opportunities.

Yeang also observes that it is therefore evident that designing with “green” or ecologically responsive design objectives in mind is vital. Indeed, these must certainly now be the prime objectives for the design community today.

The second factor that characterises Yeang’s overall work is the recognition that all those concerned with building must establish a new perception of a new building form that is sustainable future through the development of new building concepts. This new building concept is evolved from a system of design which particularly relates to the ecological design of both skyscrapers, and other large projects such as the National Library of Singapore, in which he is currently engaged.

While this book is entirely dedicated to Yeang’s architectural output, the realm of his own developing bioclimatic series of skyscrapers and beyond, and it therefore cannot substitute as a complete theoretical treatise. It is nevertheless important to place the work in the critical context of Yeang’s theories, as completely contained in his extensive writings such as The Green Skyscraper.*

The logic of tackling the scale of high-density, high-rise buildings in relation to ecological design gains particular relevance when their massive input and output of resources and waste is measured. Equally the increasing intensity of expansion in world cities is almost certain to continue the proliferation of major urban buildings, given the economics of urban land economy. Hence, Yeang’s case that the skyscraper and other major urban building types require to be designed as an ecologically responsive standard as a matter of urgency for a sustainable future. However, the limitations are also defined and recognised.

"... the problems and technical innovations for a comprehensive holistic ecological design for intensive building types remain unresolved or have yet to be invented. But this should not lead us to assume that a technological ‘fix’ is the preferred solution of design problems or that it is possible for all environmental issues to be resolved overnight.”

Yeang is calling for a change in the attitude of designers universally and for what he calls an ‘intelligent start’ on the application of techniques and ideas required to establish green design solutions as a basic expectation.

With regard to the progressive content of the skyscraper projects in this collection, it is important to clarify a fundamental concept in Yeang’s own terms:

"To avoid confusion between what is bioclimatic design and what is ecological design, we should clarify the differences. Generally, bioclimatic design is the passive low-energy design approach that makes use of the ambient energies of the climate of the locality to create conditions of comfort for the users of the building... As an emergent bioclimatic built form, it provides a viable alternative to the existing skyscraper and constitutes a new building genre; however it must made clear that bioclimatic design is not ecological design in its entirety, but only an intermediate stage in that direction. Ecological design is a much more complex endeavour."

The crucial distinction between Yeang’s theories of ecological design and those of other architects is then a vital matter of definition.
Young's own terms, ecological design is fundamentally about interconnectedness. "... the emphasis here is on the interdependencies and interconnectedness in the biosphere and its ecosystems ... the crucial property of ecological design is the connectedness between all activities, whether man-made or natural; this connectedness means that no part of the biosphere is unaffected by human activity and that all actions affect each other... Simply stated, all built systems must have a reciprocal relationship with their local environments and with the rest of the biosphere," or equally, "... the greater the adherence to the principles of applied ecology ... the greater will be the effectiveness of the ecological solution."

Related to this seminal statement are Yeang's theoretical 'interactions matrix' (see frontispiece) and his "law of ecological design"—both deserve particular attention. As a preface to this central area of Yeang's theory, several other factors require mention.

The first is the question of the "time-lag" that is inevitable between the design of a major building and its subsequent realisation, while in the meantime ideas and theoretical developments, and also technological solutions may all have advanced. At the same time Yeang also acknowledges that ecological design, in the complete sense, is still in its infancy: "... current ecological design strategies should be appropriately regarded as a transition towards the ecological ideal."

Next, it is equally relevant to outline the scope of Yeang's eco-agenda. Ecological design ... includes not just architectural and engineering design but also seemingly disparate disciplines such as landscape ecological land-use planning, embodied energy studies, recycling practices, pollution control... together with all the associated detail systems. The great importance of Yeang's comprehensive method and approach lies in the concept of "gathering and togetherness", as he describes it: "... the bringing together and integration of these aspects of environmental protection and control (previously regarded as separate disciplines) brought into a single approach to ecological design."  

What follows from this is the summary organisation of Yeang's "partitioned matrix" which unites his conception of four sets of interactions into a single symbolic form, and includes the fundamental interactions of the built and natural environments. More specifically, these are processes that occur within the system (internal interdependencies), and activities in the environment (external interdependencies). These are taken together with exchanges between system/environment and environment/system in Yeang's summary terms:

'internal and external relations and transactional interdependencies are all accounted for.'
Acknowledging that it is logistically impossible to do full justice to Yeang's extensive and evolving theory in a brief survey, it is nevertheless crucial to indicate the fundamental difference it brings to his position as an architect.

The partitioned matrix is itself a complete theoretical framework embodying all ecological design considerations. The designer can use this tool to examine interactions between the system to be built and its environment holistically and inclusively, taking account of all the environmental interdependencies. This is included in the four sets of the diagram.

Yeang 1995 model of a system and its environment and the exchanges between the two

For the purpose of developing a theory, for ecological design, we can regard our building as a system (ie. a designed system or a built system) that exists in the environment (including both the man-made and natural environments). The general systems concept is fundamental to the ecosystem concept in ecology. The crucial task in design – and similarly in any theory – is therefore to pick the right variables to be included, which are those we find essential to our resolution of the design process.

Clearly, these general frameworks cannot encompass all the resultant requirements of a perfect system. Yeang has always emphasised that the process is ongoing and that various sophistications are essential. The partitioned matrix will not do to incorporate the environmental feedback that occurs once the building is actually constructed...

As this would require a more comprehensive and complex model, yet again.

The 'partitioned matrix' for Yeang constitutes what he has described as a fundamental 'Law of Ecological Design':

"In ecological design, this 'Law' then requires the designer to look at his designed system in terms of its component parts - interdependencies..."}

The matrix allows the designer to assess the ecological impacts and to incorporate all the necessary adjustments to produce a comprehensive balanced design. Yeang's terms...

... any designed system can be conceptually broken down and analysed based on these four sets of interactions ...

Within the extensive range of Yeang's theory, the case of application in this book is essentially about the design of sustainable intensive buildings - including skyscrapers and other building types such as malls, stadiums, etc. It is therefore a priority to relate theory to architectural practice. In this regard two further statements provide clarity...

"... holistic and ecological design takes into account local and global environmental interactions; anticipatory design is forward-looking and is also environmental in that it considers effects over the entire lifetime of the built structure ... green design is also self-critical ... it considers its own effects on the environment and tries to eliminate negative impacts on ecosystems and terrestrial resources ... the green designer takes a 'balanced budget' approach, weighing environmental costs and using global resources in the least damaging, most advantageous manner possible."

This statement, in the first instance, establishes the overall context in which the essential act of design, as a process, occurs.

But, secondly the application of principles in itself, requires definition relative to actual building design:

"From the point of view of applied ecology, ecological design has essentially to do with energy and materials management concentrated in a particular locality (ie. the building site). By this (Yeang) means the earth's energy and material resources (biotic and abiotic components) are in effect managed and assembled by the designer into a temporary man-made form (for a period of intended use of 'its useful life'), then later demolished or disassembled at the end of this period, to be either reused or recycled within the built environment or assimilated elsewhere into the natural environment."
"... the designed system must create a balanced ecosystem of biotic and abiotic components or, what would be better, create a productive and even reparative (i.e., healing) relationship with the natural environment both locally and globally ... in addition one has to consider the other conventional aspects of the design of a built system (in this case the Skyscraper): design programme, costs, aesthetics, site and so forth."

Yeang has also crucially highlighted that the theoretical structure of the interactions framework can reveal "... holes in current design practice and research on the subject ... Green design, when pursued comprehensively, demands certain kinds of data, which will have to be developed and quantified where not available."

Beyond this synoptic comment there are some further observations, that relate to the central thesis of this book and to the application of Yeang's theory "... while the partitioned matrix is a comprehensive framework, it is not programmatic. That is to say, it includes all possible issues but not ... particular situations and cases. It can act as the 'law for ecological design', but it is the individual designer who has to apply that law. All that can be predicted here is the type of design issues likely to be faced by the architect of a 'green' skyscraper and other large buildings, particularly in the area of ecosystem interactions and effects ... the interactions model and the matrix present a general, overall picture of the design problems faced by architects following green principles. In essence it is a map, which allows many paths on the way from problem recognition to resolution ... What is important is that in adapting the built system to the natural environment the designer does not neglect any of the interactions defined by the partitioned matrix; how they are addressed remains individual."
Read the elements, as illustrated below. As the primary system cycle of the building system on the diagram, we can see that the design strategy must begin by optimising all the passive mode strategies... which the designer must endeavour to use to the fullest extent... (the designer's work on the skyscraper, the summary of his life work to date.) He has expanded his address in an exhaustive survey of the current and conditions that surround the process of building and design. There are two main environmental conditions to be considered, and these are the predominant factors in the design strategy... the remaining energy needs in terms of heating, cooling, electricity and ventilation should be met by those active systems powered by ecologically sustainable forms of energy...Yeung then expands on this central question of modes and systems... "It will be useful to categorise the level of operational systems provided to our skyscraper and other intensive building types, in other words the extent of its internal environmental servicing systems... into three levels of provision:

- The Environmental Context for Building
- Design Regarded as Management of Energy and Materials
- Designing the Skyscraper's Operational Systems, and
- Discussion Ecological Design...

Yeung further reflects on Yeang's extensive literature, which reveals two outstanding points relative to the skyscraper. The first has to do with modes, in this crucial connection, Yeang who regards each project and building as a progressive development in stages, has said:

"At the beginning of the production of the design brief, it should be ascertained whether it is possible to meet the skyscraper's comfort requirements largely through a design incorporating passive mode measures with a direct effect. In any event, the design strategy must begin by optimising all the passive mode strategies... which are exhibited in many of Yeang's early skyscraper projects included in this book."

"Following which, the designer must endeavour to use those mixed-mode systems that are viable and acceptable. The remaining energy needs in terms of heating, cooling, electricity and ventilation should be met by those active systems powered by ecologically sustainable forms of energy..."
- passive mode  
- mixed mode  
- full mode  
- productive mode

The provision of the basic level of systems at the passive-mode level, if acceptable to all occupants, is ecologically ideal. It requires the optimisation of all possible passive-mode systems for the locality. The full conventional systems level of servicing is referred to here as the specialised level or the full conventional systems level of servicing is referred to here as the specialised level or the full mode. The in-between or mixed-mode level is the background level of servicing.

Productive mode is the use of systems that generate energy (eg. photovoltaics). The designer must decide at the onset which of these levels of operational systems is to be provided in the building."

But, on the decisive question of defining the level of provision both for skyscrapers or other large buildings, Yeang returns to the centrality of the designer's role, and to 'interconnectedness' and the partitioned matrix:

"We can conclude that in the ecological approach, the designer must start with the premise that the environmental impact increases in relation to the increase in demands by users for living conditions beyond those of a simple existence. The first question to be asked prior to design is, 'What is to be built?' and to assess its validity and consequences generically. In preparing the design brief, the designer must find out the extent of shelter and comfort that he or she must design for ...

By considering the ecological design holistically in terms of the four factors in the partitioned matrix, it is clear that ecological design must encompass not just architectural design, engineering design and the science of ecology but also other aspects of environmental control and protection such as resource conservation, recycling practices and technology, pollution control, energy embodiment research, ecological landscape planning, applied ecology, climatology, etc. The partitioned matrix here demonstrates the interconnectedness of this multitude of disciplines which must be integrated into a single approach to ecological design.""

As far as this brief synopsis can extend, Yeang's final outstanding point has to do with aesthetics, together with economics and performance within the marketplace:

"... We might conclude here by declaring that in addition to meeting the systemic aspects of ecological design, the ecologically responsive or 'green' skyscraper or large building type must also be aesthetically pleasing, economically competitive and excel in performance. If it does not meet these criteria, it is likely that it will not be accepted by the public. The economics of ecological design (or ecological economics) need to be rationalised if business is to accept the benefits of green design ...""
"Low energy design and ecological design are applicable regardless of architectural style. Since the best opportunity for improving a building's environmental performance occurs early in the design process, it is clear then that we must at the outset make our skyscrapers and other large buildings not only ecologically responsive but aesthetically pleasing as well if green design is to be a durable proposition."

In drawing together a synoptic review of Yeang's extensive overall vision of the formation of a responsive and responsible ecological architecture, the importance of his concepts of interconnectedness and comprehensiveness are absolutely central. In practice, using Yeang's theories, the importance of the architect and designer applying the principles to the design process is equally crucial in the actual realisation of truly ecological architecture. Then, in turn, what can be achieved on a global scale, is an architecture and quality of settlement that both satisfies human need and contributes to a sustainable environmental condition.

Yeang's summary declaration describes his theoretical work to date as "... a set of ecological ideals or intentions, the full implementation of which may incur additional costs (over and above the conventional building costs) or societal changes (eg. standard-of-living or comfort) or the revision of current technological and design methods. While many of the ecological objectives remain currently technologically or scientifically unfulfilled, the framework ... nevertheless provides a point of departure from which, hopefully, these objectives will eventually be achieved in their entirety."

With this last statement in mind, it is then possible to see Yeang's development of his own architecture as a set of projects that gradually work progressively towards the ecological objective, both within the constraints of the actual commission and those of the commercial marketplace.

In the presentation of Yeang's skyscrapers and large buildings that follows the trajectory of that development towards an ecological objective is naturally revealed in the nature of the architecture itself - inflected and new forms that are signal of a truly contemporary genre of green buildings. Beginning in the early 1980s, Yeang has already spent some two decades in that relentless development, and the active production of increasingly measured and precisely designed projects are consistently emergent from his Kuala Lumpur studio.

Collectively, and taken together with his theory, Yeang's work is steadily providing an important place of world leadership in the pursuit of architecture and sustainability.

Any overview of Ken Yeang's skyscraper architecture of the last two decades will inevitably confront his relentless pursuit of ecological design, enacted throughout his growing range of projects, typologies and developing hybrid forms.

That the urban skyscraper is central to Yeang's output is self-evident, but alongside this, two other aspects of his creative activity are equally synergistic and critical. The first concerns his method, that of research, design and development (R, D & D) within the context of practice, the second is his inventive creation of vertical urbanism within the framework of the bioclimatic skyscraper.

As further background, it is fundamental to refer to his doctoral thesis, 'A Theoretical Framework for the Ecological Design and Planning of the Built Environment'. Yeang's work on ecological design and its theory emerged at Cambridge University in 1971-75, and has ever since consistently addressed the whole built environment, including architecture and urbanism. His fundamental agenda is sustainability, and in his ground-breaking thesis of 1974 he summarised his theory of ecological design:

"... it is not an architectural theory but a body of theory that is architectural. Ecological design theory, by nature of the interconnected and holistic characteristics of the earth's systems, affects all aspects of human activity that have an impact on the natural environment, consequently, ecological design theory can include, besides architecture, such seemingly disparate fields as energy production, efficient utilisation, waste recycling and reutilization." 31

Yeang has consistently stressed, from the outset and his entry into architectural practice in Kuala Lumpur in the mid-1970s, that all his theory needs is to be advanced and developed through systematic application and testing via the implementation of real architectural projects. In turn this attitude is the foundation of his creative process, both in terms of technique and his form-giving in architecture.

In reviewing his theory and practice, Yeang has emphasised that:

"Crucial to our entire agenda and work is the focused methodology of research, design and development (R, D & D). This involves an approach to the craft and practice of architecture that demands research as the basis for design and, further, insists on physical implementation as the testing grounds for ideas and their poetic interpretation." 32

Yeang's R, D & D work over the last two decades, especially as applied to tall buildings, has resulted in his invention of a new building type: the bioclimatic skyscraper. In turn this typology incorporates his additional principles and spatial development of vertical urbanism.

This trajectory of development is evidenced in a particular set of towers selected to exemplify Yeang's architecture.

30 "Bioclimatic Skyscrapers" Ken Yeang, Artemis 1994, see essay 'Theory & Practice', Ken Yeang, p 16
Although there is precedent in Yeong's earlier work, Menara Mesiniaga is the archetypal summary of the bioclimatic sun-path type, which exhibits the clear principles of solar shielding and orientation, coupled with the orientation of planted skewcourts and atrial recessions. Details such as sun-shading sparkles, and size and profile of protective louveres are all subjected to precise geometrical arrangement related to sun angle and path, while the materials specification throughout is related to studies of embodied energy. The external form is appropriately dominated by the spiralling planting of the courts and atrial spaces that are the signal of Yeong's bioclimatic architecture, which is significantly low energy in operation. At the same time the building exploits the quality of the pleasant tropical climate, uniting office workers with the natural environment.

The bioclimatic skewcourts thus stands as an exemplar and in sharp contrast to the sealed, air conditioned, centrally cored and energy-consumptive form of its essentially North American counterpart.

The four towers represent progressive developments within the range of Yeong's bioclimatic series.

Tokyo: Nara Super Tower is essentially a spiralling form, rotating within a controlling circular geometry, which extends several theoretical propositions. The Singapore ETDT Tower and the Kuala Lumpur BATC Tower are both signature forms, displaying three organic plan arrangements that incorporate ideas for vertical urbanism. While these three are not built, the fourth project for the Pulau Pinang UMNO Tower was completed in 1998 and essentially wind wing-walls, applied to a constrained rectilinear plan, are the central innovation.

This series also demonstrates Yeong's designs as a progression from formal geometry to a free organic expression. The formal progression is matched by an expanding ecological and urbanistic investigation.

**TOKYO-NARA HYPERTOWER 1993**

This is a project that both extends and experiments with several theoretical ideas founded in earlier works, in particular that of Menara Mesiniaga, Kuala Lumpur 1992. Both Mesiniaga and Nara Tower forms are constrained within the outline of a circle and contain the principle of a vertical spiral of boundless dimensions. While the KL Mesiniaga Tower is a mere 15 stories, the Nara Tower can be visualised and extended to 210 stories, or 880 metres high, almost double the vertical dimensions of Pelli's Petronas Towers in Kuala Lumpur.

The Nara Tower project provided Yeong with the opportunity to realise and expressively confirm many of these theoretical ideas. The project represents a summary of his research to 1993.

"... into the nature and evolution of tall buildings ...

The central idea in the project design and its conception are dominated by the spiral floor-plate structure fastened with vertical landscaping, which loops around and penetrates the form and its progression of vertical spaces. This is a direct development of the Mesiniaga principle, and in the same way the abundant foliage assists in cooling the building mass. Equally, the planted lingers of floors and atrial spaces contribute to the control of air movement within the overall structure. In this case the calculated, assembled mass of planting balances the biosystems with the mechanical systems in a symbiotic relationship that yields a stable environment - a bioclimatic machine a habitation.

In response to the maintenance needs of the vertical landscaping, glazing and panel cladding systems, Yeong introduced an innovative robotic arm as a form of 'thermo-picker' on moveable trolley. These travelling devices move on an external track that spirals the tower in vertical, expressive circulation.

The structural system is a tour de force - a three-point equilateral triangle defines a trapezohedra primary honeycomb structural frame, linked and set within the circular geometry of the robot track system. This matrix provides a support system for the radial/spiral arrangement of organic floor plates (described as pectrum shaped).

As the floor plates are rotated at alternative floors, the overlapping layers provide a natural shading system. This shifted pattern allows the introduction of hanging gardens, inter-floor bracing, ventilation and cooling system networks. The main structure is penetrated centrally by a pivotal cable stay mast, and this element, together with the outer triple V-form structures, define the positions for batteries of vertical transportation. The floor plate spiral shift also creates variations of atrial space that are further infused with terraces, internal courts, private gardens and skewcourts.

Throughout, Yeong envisaged his first principles of vertical urbanism. These included principally: mixed occupancy such as offices, apartments, hotels and communal facilities; skewcourt oases, the equivalent of green parks; and the atrial spaces as a public areas of movement, vistas, air and light. The skewcourt oases, located at regular vertical intervals, provide major breaks in the built volume - a form of suspended natural park, introducing fresh air and acting as the Tower's lungs, distributing via the atrial voids and essential airflow, while insulated from the city beneath. The atrial network of spaces, winding within the tower, provides a sheltered interaction of walkways, bridges and stairwells - a pedestrian system of routes, open to the environment but particular to the tower itself. Taken together with the central core, these elements provide an overall system of wind-flues, which bring wind to inner parts of the building, with adjustable dampers. This principle has been further developed in the wind wing wall system used in the Penang UMNO Tower.

As with the Mesiniaga Tower, the lift and service cores are laid defensively on the east-west axis of the sunpath to absorb the maximum quantity of solar gain. The cooler facades on the north-south axis are, conversely, more open with clear glazing and atrial voids, echoing the earlier precedent. In the same bioclimatic tradition the shielding and glazing systems are orientated to resist solar gain. The east-west facing sides are more solidly glazed, with cast and perforated metal cladding - selected for qualities of reflection, weight and structural capacity. And again, the north-south faces of the form are equally legible by the open louveres, tiered sunshades and clear glazing in response to the lower exposure to the sun.

The vast spiral form of this bioclimatic super tower is intended to.mediate independently of the polluted lower city beneath, reaching into the inhabitable upper atmosphere, in Yeong's words "... at the edge of the sky". Armoured against solar gain and strategically opened to introduce natural ventilation, the overall spatial composition and functional mix offers the possibility of a new form of urban life.
The design for the UOL house, our architectural model in the Urban Redevelopment Authority's urban renewal project in Singapore, is a hybrid form based on a vertical layout that addresses the site's topographical requirements. The upper two levels consist of two living boxes that are linked by a covered walkway. The ground floor, consisting of a large open space, is designed to function as a social and entertainment area.

The project's main focus is on creating a transition between the public and private realms. The main entrance is located on the ground floor, leading to the living room on the first floor. The second floor contains the bedrooms, with each room having its own balcony. The house is designed to provide privacy while still allowing for social interaction.

The design is also intended to be sustainable, incorporating features such as solar panels and rainwater harvesting systems. The use of local materials and the incorporation of green spaces and courtyards further enhance the project's environmental sustainability.

The house is designed to be adaptable, allowing for future modifications and expansions. The open floor plan and the use of natural light and ventilation ensure that the house remains comfortable and energy-efficient.

The UOL house is a model for future urban living, blending functionality with aesthetic appeal, and is a testament to the importance of sustainable design in today's urban environments.
Yeang has made a crucial point in the design of the EDITT Tower in that the major issue in the urban design of skyscrapers

"...is poor spatial continuity between street-level activities with those spaces at the upper-floors of the city's high-rise towers ..."

in the conventional case, which is based on repetitious, physical compartmentalisation of floors within an inherently sealed envelope.

Yeang's central manifesto is that urban design involves 'place making'.

In the EDITT Tower he has applied this principle with conviction:

"...in creating 'vertical places', our design brings 'street-life' to the building's upper-parts through wide landscaped-ramps upwards from street-level. Ramps are lined with street activities: stalls, shops, cafes, performance spaces and viewing decks, up to the first six floors. Ramps create a continuous spatial flow from public to less public, as a 'vertical extension of the street', thereby eliminating the problematic stratification of floors inherent in all tall buildings typology. High-level bridge-linkages are added to connect to neighbouring buildings for greater urban connectivity."

In addition to the consideration of public space and circulation, Yeang added an analysis of views to enable upper-floor design to have greater visual connectivity with the surroundings. In Singapore, with its superb seacoast location, this is a significant factor, and rightly exploited.

But, it is the manipulation and integration of the ramp, within the form and function of the project, that emerges as the fundamental precept of the architecture and its manifestation of public space and use. In common with the early projects of Le Corbusier, and more recently Richard Meier, the ramp is once again celebrated here as a symbolic notation, and the visible expression of the promenade architecture.

Aside from the abundant, spiralling landscape of indigenous vegetation which assists ambient cooling of the facades, two further elements appear foremost in the form-giving process. These include the curvilinear rooftop rainwater collector, and the attendant rainwater facade collector scallops, which form the rainwater collection and recycling system. Equally the extensive incorporation of photovoltaic panels, as a major formation on the east facade, adds a further level of formal detail residual in the overall bioclimatic discipline, towards reduced energy consumption.

In this case, Yeang's ecological response begins with an extensive analysis of the site's ecology. This exhaustive analysis of ecosystem hierarchy, determines that this site is an urban 'zero culture'. Consequently, this is a crucial determinant, which focuses the design approach towards the restoration of organic mass, which will enable ecological succession to replace the inorganic nature of the site, in its current urban state of devastation.

This policy is manifest in the planted facades and terraces of the project, which are continuously ramped upwards from the ground-plane to the roof-summit level and constituting a significant proportion of planted to useable floor area. Yeang included a survey of indigenous planting within a 1 mile radius of the site in order to select species that will not compete with those already present in the locality. Sustainability underscores every move.

Otherwise, Yeang's ecological design process includes a further series of significant analyses. Perhaps most important is to submit the project to a 'loose-fit' philosophy, which will enable the building to absorb change and refitting over a life-span of 100/150 years. Overall, this allows conversion from the expo-condition to possible office use, with a high level of floor occupation efficiency. This involves removable partitions and floors, reuse of skycourts, mechanical junctioning, which enables future recovery of materials, all within a matrix that is based upon flexibility as a paramount condition.

In addition, Yeang introduced a series of systems and assessment procedures that further underscore the ecological design of the tower. As well as water recycling and purification associated with rainwater and grey-water reuse, the project includes sewage recycling, solar energy use, building materials' recycling and reuse, together with natural ventilation and 'mixed-mode' servicing. The latter optimises the use of mechanical and electrical servicing so that both mechanical air-conditioning and artificial lighting systems are reduced, relative to the locality's bioclimatic responses. Ceiling fans with demisters are used for low-energy comfort cooling. Wind is also used to create internal comfort conditions by the introduction of 'wind-walls', that are placed parallel to the prevailing wind to direct airflow to internal spaces and skylights, to assist breeze cooling.

Finally, the whole material fabric and structure of the tower were subjected to an embodied energy and CO₂ emission assessment, in order to understand the environmental impact of the project, and to define a balance between embodied and operational energy content.

While these methods are neither unique nor overly new in themselves, it is the co-ordinated collective effect of their application in Yeang's architecture that signals its ecological attitude to design, and provides the basis for development in following projects.

KUALA LUMPUR BATC SIGNATURE TOWER 1997

In order to describe the Signature Tower adequately it is essential to place it in the context of the overall development to which it belongs, as a key component.

The Business Advancement Technology Centre forms a massive mixed urban development, incorporating some university faculties on the Semarak Campus of the Universiti Teknologi Malaysia. The site is also related to the Central Business District of Kuala Lumpur. As both the Multimedia Super Corridor (MSC) and the Kuala Lumpur City Centre (KLCC) are located less than 2 kilometres from the campus site it became strategically obvious to further expand its potential and develop the overall site into a Satellite MSC, in a synergistic relationship with the MSC itself. In principle, the project incorporates major educational, research and development and electronic commerce related activities.

The project is organised as a collaboration between the university, as landowner, and a property developer.

As an integrated urban masterplan, the project represents one of the largest proposals Yeang has designed, and opens the opportunity to demonstrate the principles of his bioclimatic approach as applied to the design of tall buildings, and a larger high technology urban village with transportation infrastructure.
The 47 acre site is envisaged as a landscaped park within which the buildings are placed and separated by a central series of public plazas, boulevard walkways and controlled car access routes. The rapid transit system (RT) forms a central spine with a station at the mid-point junction between retail, commercial and university facilities.

The site is divided, therefore, into three zones. A central north south zone of the major public spaces and activities, edged on the north and south by two further fluid parkland areas into which the array of facilities are inserted and attached to the central V-form spine. The 60-storey Signature Office Tower and the five, 30-storey office towers are sited within the parkland areas, at part of this ensemble.

As landscaping is applied to the entire development, the whole immense project viewed from the pedestrian scale is seen as a grand park with the buildings located and immersed within this natural setting. The towers are accessed via the mounted landscaped ground plane of the site, while water gardens and soft landscaping are introduced to enhance the pedestrian routes throughout the site in general. Many of the routes provide weather protected, semi-enclosed pedestrian circulation, free of vehicular intrusion. This is a principle, related to the tropical climate that has it origins in Yeang's earlier works, such as his conceptual proposals for the Tropical Venusiah City of 1987.

Related to the overall principles of a landscape concept, landscaped and terraced skyrises have been incorporated at intervals in the office tower floors as they ascend, providing both an amenity for relaxation, and a continuous visual and physical linkage, threading together all studies. The vertical urbanism, in this case, accord with a vertical ascension of public gardens and parks. This concept is further supported with Yeang's incorporation of public places in the sky - the amenities of a traditional city, but vertically located in the tower forms. Thus, in the instance of all six towers for the BAIC masterplan, the principles Yeang employed for the Singapore EDTT Tower are now enacted into a major exposition of the bioclimatic skyscraper. In turn these tall buildings incorporate integrated Building Management Systems to control internal conditions by monitoring, the immediate, external surroundings through a series of environmental sensors located on the roof - effectively Yeang's version of a bioclimatic weather station.

The significance of the BAIC Towers lies in the fact that they exist as a part of much larger idea, centred on a harmony of bioclimatic principles, and framed within the urban master plan, as a whole. The BAIC Centre and Branch Campus of UTM contains a School of Advanced Education Programmes to high technologies catering for 5000 students. This is coupled with industry, research and development centres for 20 institutions, in order to advance business opportunities arising from the research. The associated High-Technology Office Park houses companies involved in the advanced technology industry, including IT and multimedia, and provides these occupants with the shared use of super-capability computer facilities as a basis for a significant centre of innovation.

The masterplan also incorporates major convention and exposition centres, information and resource centres, and a Multimedia and IT College. Each of these facilities occupy an offset leaf edge site as part of the spatial arrangement. Further public facilities include a major theme mall for retail entertainment and recreation via multimedia applications, residential blocks, to house students, researchers and office workers; a five-star hotel for visitors and tourists, with fully equipped business centres.

**The Tropical Venusiah City, Ken Yeang, Longman (Australia) 1987**

These proposals date on the concept of semi covered, shaded pedestrian circulation areas for the tropics city.
All this diverse provision is underscored by the system of public parkland within the site, whose high greenery and landscaped contributes towards an environment that enables high business activity and related research enterprises. A main boulevard system structures the site in vehicular-free conditions that encourage public use with covered pedestrian pathways, or the alternative of an air-conditioned Internal Rapid Transit System, which provides movement within the site, with links to the outer ERT system of Kuala Lumpur.

The 40-storey Signature Office Tower is the singular landmark, vertical event of the BAC Masterplan, counterbalanced by the horizontal mass and spares of the central plaza and spatial facilities.

The Signature Tower occupies a central site on the western parkland of the project, with larger sides of its cranked rectangular plan facing north and south, and the eastern face typically solar shaded with service cores, elevators and restroom clusters. The sunken tower levels incorporate escalator bays serving the centre of the form up to level 4. Above level 12, two systems of pedestrian ramps alternate on the outer north and south faces up to level 40, reducing to the south face only from level 48 through to 60. As with the Singapore EDIT Tower, these ramp formations are an important part of the building's expression of public circulation and the notion of vertical urbanism, seen as a hierarchy within the tower form. Otherwise, the dominant composition elements are the two massive vertical landscape parks occupying a large area of the atrial voids and skyscrapers at the higher levels. These are augmented by a ramping park at the base, and ten other smaller parks distributed over the height of the building's section.

At the central and most prestigious flexible office facility for the whole development, the innovative bioclimatic design offers a first-class daily environment for its occupants. The interminions of restaurants, skyplazas and special gallery spaces, with the overall development of the vertical gardens, park and extensive skyport voids, taken together, make Yeang's most flamboyant tower project of his current series.

On another level, much of the technical innovation of the Singapore EDIT Tower could be expected to appear, when the project is ultimately realised.

The Signature Tower summarises Yeang's vision of the Skyscraper as the Vertical City-in-Sky. This is primarily achieved through the vertical coupling of multiple programmes of space use, within the overall programme of the tower as a spatial construct. This idea is then further emphasised by a three-tier hierarchy of circulation systems, and the system of vertical landscaping, parks and squares both ascending and crossing-cutting the overall form. The singular force of the concept is perhaps best conveyed in Yeang's coloured elevational notations of his triplicate vision.

Beyond the tower itself, however, the most significant impact of the total masterplan is the application of bioclimatic principles to the overall urban design of the BAC complex, regardless of type.

PEHANG UMNO TOWER 1995–98

The UMNO Tower is one of a series of projects that Yeang developed and built between 1993–98, using slim rectangular plan forms on dense urban site locations. These projects include Central Plaza, and the Bidadara Tower, both in Kuala Lumpur, and realised between 1993–96. While all these towers were designed within the framework of Yeang's bioclimatic agenda, the UMNO project for downtown Penang is singularly distinguished by its concentration on natural ventilation and the development of wind wing-walls in this connection.

The thin-elongated urban site-plan of the tower is situated at the junctures of Jalan Zainal Abidin and Jalan Macalister, resulting in the extended longitudinal facades being exposed to a south-east or north-west orientation. This in a function of such valuable urban-land locations.

The 21-storey tower design responds with a vertically solid solar-shading wall of elevators, staircases and restrooms with service cores, all in Yeang's other bioclimatic projects. In this case the shield-wall not only protects the critical south-eastern face from solar gain, but it projecting planar terminals, at the north and south extremities, form two of the wind wing-walls that are particular to the natural ventilation strategy of the project and its office spaces.

The base of the UMNO Tower contains a deeply recessed, double-height banking hall, together with the glass-canopied main entrance raised on a shallow podium and accessed from Jalan Macalister, the main thoroughfare. The base also contains the main plant spaces and car-ramps that give access to parking areas on levels 2 through 5. Level 6, the principal occupied floor, houses an auditorium for meetings and assemblies. Above this rise, 14 floors of office floor space for let. Several floors, such as level 9 and 12, have extensive break-out roof terraces, and the roof levels are shielded by a steel-structured, elevated shade canopy.

The solar shield-wall accommodation of elevator lobbies and restrooms are naturally sun-filled and ventilated, and typically accord with Yeang's low-energy agenda. Similarly, all office floors, although designed to be air-conditioned, can be naturally ventilated. The thin plan-form, of each floor-plate, means that no desk location is more than 6.5 metres distant from an operable window, enabling all office users to receive natural sunlight and ventilation. Although the project was originally designed for tenants to install their own split unit air-conditioning, due to expected low rental rates in Penang, ultimately a central air-conditioning system was installed. The design for natural ventilation in its realised form, thus provides a back-up system for the building, in the event of power failure.

Major sun-shaded installations on the curvilinear north-west office are solar orientated, and outrigger shield-shades are provided to the carpark floors, also on this facade.

But, it is the wind wing-wall system, which in this case dominates the streamlined form of the UMNO Tower architecture, and it is perhaps significant that Yeang has persistently compared the vertical-scale of the building, to the aerodynamic form of one to a one and a half times the length of a typical jumbo-jet aircraft. The symbolic inference of building-aircraft, and the cross-referencing of the sophisticated serviced shell, has long existed in Yeang's essays and in certain projects, such as this, comes closer to a transferable vision.

The architect's own notes on the development of the wind wing-wall design are of significance, as they describe his system of research and application:

"The building has wind wing-walls to direct wind to special balcony zones that serve as pockets with airlocks, having adjustable doors and panels to control the percentage of openable windows, for natural..."
ventilation. This building is probably the first high-rise office (tower) that uses wind as natural ventilation for creating comfort conditions inside the building. For internal comfort as in this building, a higher level of air-change per hour is required. Here, we tried to introduce natural ventilation at point of entry, rather than create suction at the leeward side. To create pressure at the inlet, a system of wing-walls to ‘catch’ the wind from a range of likely directions (are introduced). The wing-walls are attached to a balcony-device with full-height sliding doors. The placements of the wing-walls and air-locks within the floor-plate are based on the architect’s assessment from the locality’s wind-data. The wing-wall cum air-lock device is of course, experimental, and site verification with CFD analysis indicates that this device worked reasonably well. Experience from the project, will enable the architect to further develop the device for other projects."

And this has indeed been the case for the design of the EDNO Tower for Singapore uses the same principles to create internal comfort conditions, by the incorporation of wing-walls as an integral device, in the natural ventilation strategy. These examples not only demonstrate Yeang’s R, D & D strategy in a sequence but they also point up the process which informs his architectural expression — a process that allows functional low-energy design to bring sophisticated form to what would otherwise be just an office tower in the conventional sense. In creating the bioclimatic skyscraper, Yeang has not only evolved a new type, but has developed both low-energy architecture and the spatiality of vertical urbanism.

Further it has been said of Yeang’s work, that

"... his towers as they ascend in Kuala Lumpur or Penang or Ho Chi Minh City seem, in their paradoxical mix of orders and desires, to achieve a synthesis exactly appropriate to the cultural promise of South-East Asia, their warrior-like stance ready for the economic revolutions of the new century'’.

The fact that Ken Yeang has brought about his sustainable architecture, and a range of achievements within a harsh commercial environment, is itself remarkable, but even more important is the fact that his work and the improved environments his buildings offer, has affected the quality of life for countless occupants for the better.

Ivor Richards
School of Architecture
Planning & Landscape
University of Newcastle
UK
May 2009

* UUMNO Tower. Ken Yeang, project profile and notes, 1998
* Yeang, Bioclimatic Skyscrapers: Asia Architecture for a New Indoor, Art & Culture, op cit p 8
solar
Within the rigorous development of any new typeform, certain projects emerge which embody and summarise all the significant principles that are applied, and configure these into an elegant and mature formal order – Menara Mesiniaga exemplifies the characteristics and significance of such a project.

Although only 15 storeys in height, this tower – while being clearly grounded in the basics of Menara Boustead – can be extended as a type, to create great leaps of development, such as Yeang’s 80-storey Tokyo-Nara Tower project.

Central to this iconic summary of the low-energy, passive-mode sunpath type are the principles of solar-shielding and orientation, combined with the implementation of multi-height planted skycourts and atrial recessions coupled into a beautiful spiral-form, gathered into a pure circular plan. Details of attached sun-shading spandrels and protective sun-louvres all reach a stage of precise and sophisticated design related to sun angle and path, in the overall conception and its constructed reality.

That this project, which stands on the outer threshold of Kuala Lumpur city, has been the subject of multiple publications that demonstrate its significance also measures its importance, but it is equally noteworthy that the building has received international acclaim in the form of awards for architecture.

The Mesiniaga Tower is essentially a regional headquarters building, in this case for IBM’s Malaysia agency. With its commanding position, the building both exploits the qualities of the local, ambient tropical climate and the magnificent vistas to the surrounding hillside landscape.

Yeang’s modest description, first cast in 1994, belies the archetypal nature of the project as a first-rate exemplar of bioclimatic architecture:

And, leaving aside the later UMNO Tower of 1995–98, and its subsequent development of the ‘wind wing-wall’ principle with its expressive consequences, Mesiniaga remains as a supreme architectural statement:

"... the most striking design feature is the planting which is introduced into the facade and the skycourts, starting from a three-storey-high planted mound (a berm) and spiralling up the face of the building. Triple-height recessed terraces towards the upper part of the building are also planted. These atriums enable the
channelling of a cool flow of air throughout the buildings transitional spaces while the planting provides shade and an oxygen-rich atmosphere. Curtain wall glazing is used only on the north and south facades to moderate solar gain. All the windows areas facing the hot east and west faces have external aluminium fins and louvres to provide sun shading. Glazing details allow the light-green glass to act as a ventilation filter, protecting the interior without totally insulating it. Terraces are provided for all the office floors, and have sliding full-height glass doors to control the extent of natural ventilation (when required). Lift lobbies, stairwells and toilets have natural ventilation and sunlight. The lift lobbies do not need pressurisation for fire protection.

What Yeang is describing constitutes the major low-energy elements of the design, which, in turn, greatly enhance the quality of life of the office occupants. These ideas are coupled with the internal occupation concept of enclosed rooms such as conference spaces being located at the core of the plan, while the work stations encircle the periphery ensuring good natural light and views to the distant landscape. The terraces provide excellent break-out spaces into the external environment – an extra facility that relieves and enlivens the working day.

The pure, circular plan is surrounded by four pairs of major circular structural columns, which emerge at high level as roof masts. The major cluster of elevators and service spaces are situated outboard on the eastern face and the skycourt terraces rotate clockwise and upwards, providing a different plan form at each level. The resultant form is a loosely defined cylinder encircled with a sheath of detached spandrels and louvre elements. At the same time, the cylinder is grounded in the berm and crowned with rooftop facilities.

The summary result is both simple in conception and outstandingly clear in its resolution – all of Yeang’s elements of the bioclimatic skyscraper typology are brought together into his first iconic made piece

owner
Mesiniaga Sdn Bhd

location
Subang Jaya, Selangor, Malaysia

area
Total nett (office) area 6,761 sq m
Total net non-office (e.g. gym, cafe, etc) 1,476 sq m
Balconies and skycourts 1,381 sq m

Mechanical rooms 1,424 sq m
Carpark (basement) (145 bays) 404 sq m

plot ratio
1.16

design features
• The building brings together the principles of the bioclimatic approach in the design of tall buildings developed over the previous decade by Yeang. In particular, the building has the following features:
  • Vertical landscaping (skyvort) introduced into the building facade and as the "skyvorts". The planting starts by mounting up from ground level to as far up as possible at one side of the building. The planting then "spills" upwards across the face of the building with the use of extensive terraces (skyvorts)
  • A number of passive low-energy features are also incorporated. All the window areas facing the hot sides of the building (east and west sides) have external louvres as solar shading to reduce solar heat gain into the external spaces. Those sides without direct solar radiation (the north and south sides) have unshielded sunlit-walled glazing for good views and to maximise natural lighting
  • Lift lobbies are naturally ventilated and are sunlit with views to the outside. These lobbies do not require fire protection pressurisation (i.e. low-energy lobby). All stairwells and toilet areas are also naturally ventilated and have natural lighting
  • The skylight is the skylight provision for panel space for the possible future placing of solar-ifs to provide back-up energy source. BAS (Building Automation System) is an active intelligent building feature used in the building for energy saving

1995 AGA KHAN AWARD FOR ARCHITECTURE

jury citation

"Yeang has boldly designed a meaningful tall building in a tropical climate. Eschewing the box-like curtain wall structures so common in corporate office buildings, this project promotes a new language that pushes out parts of the structure and wraps a spiralling series of interactive open gardens around the main core buildings. It opens the kind of architectural debate in which the corporate world generally, and the Muslim world more specifically, can fruitfully engage"
Diagram showing partitioning of offices at the centre of the floor plate rather than at the periphery to enable the greater number of users to have access to daylight, views and an openable window.
The three-storey planted berm base, a major formal element, houses entrance lobbies, computer suites and below underground car parking in sheltered basements. At the top end, a roof-level sun terrace is covered with a sunroof of trussed steel and Aluminium. Locally known as the ‘flycatcher’ this shading structure filters daylight over the swimming pool and the curved roof form of the high-level gymnasium. This figure structure also provides a site for the future installation of photovoltaic cells - as an active contributor to the building’s energy requirements. In addition, the project is fitted with a range of automated systems to reduce energy consumption by both equipment and the air-conditioning installation.

This project also provokes questions of aesthetics and architectural expression. In its effortless formation, the resultant architecture is the pure product of principles and geometry – there is not a trace of applied formal imagery nor any reference to Malay tradition, only to climate and global position.

"... the architectural zeitgeist is expressed through technology and materials, state-of-the-art thought and attitude and the incorporation of climate and lifestyle principles as a contemporary translation of context ... Emotive references to traditional materials and forms are avoided, an attitude validated from a realistic position that proposes a Malaysian architecture for the 21st century, very different from its historical origins. This is an open attitude that can absorb change. It is also an intelligent reflection of a polyculture establishing a positive identity as a collective, through abstract contemporary form."

The diagrams inform how building configuration (e.g. location of service cores) can optimise the passive-mode strategy to result in a low-energy design.
Jumping Out of the Glass Box

Susan Berfield

Of all the ways to divine the spirit of a city, perhaps the most telling is to get a fix on its coordinates. Yeang believes. A city's latitude determines its climate, and climate shapes. Yeang is the most durable aspect of a place and has to be the first factor in design. When it is, the design is always indigenous and reflects the place. The firm's most recently completed project, Menara Mesiniaga, the HQ for IBM's Malaysian distributor, is its best known. The 16-story building, by far the firm's most adventurous, is nonetheless environmentally logical. The untrained observer needs only a minute to see how this cylindrical mass of steel and glass resting on eight columns makes sense. Most striking is that Menara Mesiniaga's exterior is neither sealed nor static. Yeang carved a series of planted terraces or skylights as he called them, into the building. They spiral around the tower's perimeter, providing shaped outdoor sanctuaries and absorbing some of the sun's heat. He also replaced the building's "skin" with aluminum screens and strips are designed to minimize the impact of the sun at some points and to allow more light to penetrate at others. Yeang experimented with the building's interior as well. He placed workstations along the edges of each floor and private, glass-partitioned offices in the centre to allow everyone to work in a naturally lit space with a view.

Menara Mesiniaga

Building as a Venus Flytrap
Architecture Beyond Architecture

A New Direction in Building Design

• A new direction for a new form of building design.

1. **Energy Analysis**: An energy analysis of the same building was conducted using a computer-generated analysis tool to check for energy improvements. The results indicated that the building could be improved by approximately 15%.

2. **Lighting Design**: The lighting system was designed to be energy-efficient, with the use of LED lights and motion sensors to reduce energy consumption.

3. **Building Automation**: A building automation system was implemented to control various aspects of the building, including lighting, temperature, and security systems.

4. **Thermal Performance**: The building's thermal performance was improved through the use of insulated glass and a well-insulated envelope system.

5. **Water Conservation**: Water conservation measures were implemented, including the use of low-flow fixtures and rainwater harvesting systems.

6. **Active Design**: The building's active design includes features such as solar panels and a green roof to generate energy and reduce carbon footprint.

7. **Sustainability**: The building was designed with sustainability in mind, incorporating materials and processes that are environmentally friendly.

8. **Occupant Comfort**: The building's design focuses on occupant comfort, with attention paid to lighting, temperature, and acoustic environments.

In conclusion, this new form of building design not only improves energy efficiency but also enhances occupant comfort and sustainability.
Encyclopedia Britannica, Yearbook of Science and the Future

"An example of an environmentally innovative building, deriving its quiet beauty from experiencing the inherent truths of its being. The tower’s form evolved from a rational response to the objectives of the original brief and with respect and regard for the landscape and the building’s surroundings. The massing of its circular form came from the remotely positioned articulation of an innermost circular viewing tower, enclosed garden terraces, and balconies that form an exterior skin that serves to create a vertical exterior space tone. Additionally, the pavilions developed provide natural light and ventilation in the reception lobbies, plan of all levels, and roof rooms."
Following the completion of Menara Aman in 1992, several high-rise office buildings in Kuala Lumpur were developed in the city's Golden Triangle. Kuala Lumpur and Penang each have Menara TA1 and Central Park, both sited in the city's central areas. The UMNO project for Penang was dealt with separately, and the two towers have almost identical programmatic conditions and formal similarities.

In both cases, it is the plan form that is of principal interest. The Menara TA1 plan is a simple shape with a tower form, and on the west face Central Park incorporates a complete plan shape with stairwells and service courts. While each tower has diagonal walls, and thus the great mullion of the plan, the Menara TA1 plan has a more straightforward form with fewer internal walls. The UMNO project for Penang has developed this condition as a cigarette-packet form.

Generous, naturally ventilated office courts are a feature of Menara TA1, and in Central Park the plan form is occupied by all service courts - on the roof level, the plan form is occupied by all service courts. Each tower has a diagonal wall, and diagonal walls are a feature of both Menara TA1 and the UMNO project for Penang.}

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Menara TA1 and Central Plaza (37 and 27 stories respectively) in Kuala Lumpur’s Golden Triangle and UMNO Tower (25 stories) in central Pulau Pinang form a set: each tower has almost identical programmable characteristics but with varying site conditions and orientation.

The towers all incorporate a plinth of seven cars-parking floors with generous covered and naturally ventilated entrance courts, together with retail facilities such as banking halls and restaurants at ground level. Above the parking floors, the lettable office spaces all in corporate perimeter columns to yield the maximum free floor plate area. Each tower also has some communal uses at roof level, such as a terrace garden or swimming pool, and all incorporate some form of vertical atrium or skycourt.

The towers of TA1, Central Plaza and UMNO are all for multiettable occupancy, and are realised on slim, restricted urban sites in high land-cost locations with exacting construction budgets. Essentially these towers represent the acid test both of Yeang’s philosophy and his ability to deliver added value in a highly competitive marketplace. The crucial factors that make of these office building a user-friendly experience are all functions of Yeang’s bioclimatic agenda. Astute design decisions on orientation result in elements such as lift cores (usually naturally ventilated and daylit) acting as solar shields, plan shaping to reduce exolation; natural ventilation options for the office spaces related to ‘thin’ plan forms (also a function of the site plan) and the incorporation of painted balconies and recesses together with eggcrate and louver solar shading. Northern facades are fully glazed to permit strategic views, often to distant hills.

While the orientation, the variety of forms and structural innovations are generated largely by climatic concerns, each of these design elements is also related to the economical provision of floor plates. The principles of Yeang’s bioclimatic agenda are laced with his concepts of vertical urbanism. As a set, these towers incorporate an increasingly sophisticated range of materials and detailing, including marble and laminated float glass, and display a range of whole-building colour types, from pink (Central Plaza) to white (TA1).

Taken together, the three towers provide proof of Yeang’s ability to develop a strict topology and deliver a marketable product. Perhaps equally significantly, the marketplace is gradually coming to recognise that his architecture offers much more than commercially acceptable development. Ken Yeang’s studio has a slogan posted conspicuously on a wall: ‘Everything depends on execution, having a vision is no solution’. However, his bioclimatic agenda is also a vision, and it continues to supply a real solution to the problems of contemporary architecture.
notes
1. The contractor shall provide and leave in place until testing elements are constructed. Such temporary bracing will be necessary to stabilise the structure during erection.
2. All workmanship and materials shall be in accordance with A S 4100.
3. Welding shall be performed by an accredited operator in accordance with A S 1554, electrode E48XX or WSBX to be used.
4. The ends of all tubular members are to be sealed with normal thickness plates and continuous fillet weld UNO.
5. All RHS and CHS members are to be grade 350 MPa UNO. All other steel to be grade 250 MPa.
6. Except where otherwise shown, welds to be 6 mm continuous fillet.
7. All bolts, nuts and washers to be galvanised.
8. Bolt type 4.6/5 - commercial bolts of strength grade 10 to AS 1111.
The client, the Chuang Group, a Hong Kong public listed company (the Malaysian branch of which is called Malview Sdn Bhd), selected Yeang from the previous client. The site in fact had three different owners before the current design was formalised. The Chuang’s Group wanted a prestigious building that would give them value for money with maximum rentable space - and a strong corporate image, which they believed would most successfully be achieved with a ‘hi-tech’ look. Yeang relates the tale of seeing the client in Hong Kong, and being told, as they gazed out of the window at Norman Foster’s landmark Hong Kong and Shanghai Bank “I want something like that.” Yeang is not used to being dictated to by his clients. His philosophy is to ask the client for “the budget and the total area, and leave the architecture to me.” But the image of Foster’s bank appealed to him, and the strong visual line of the cross-bracing on the east and west facades, and the high quality of detailing both inside and out, reflect the Hong Kong example.

However, the bracing is more than a nod to “Western” precedents, and is fundamental to the structure of the tower. In order to increase the size of the floor plates and provide a column-free interior, a hypothetical middle row of structural columns of reinforced concrete were omitted. The brace therefore compensates for this and prevents the tower from swaying. Most high-rise buildings throughout Malaysia are still concrete - as opposed to steel - frame, due to the availability and therefore expense of steel, although this is slowly changing. Central Plaza is no exception, and is clad in solid aluminium panels, tinted a distinctive rose colour using fluorocarbon paint. The glazing is tinted to match. The structural frame continues beyond the roofline of the tower, with the theoretical provision for expansion - although this would be highly unlikely, given the expense required to create and service what would probably only amount to one more floor. Two characteristic Yeang spikes complete the frame - strictly decoration only. The roof is occupied by a swimming pool, which sits on the concrete slabs like a giant ice-bucket, clad in slate tiles, and reached via a curved steel staircase. The cleaning track around the circumference of the pool doubles as a bench. Palm trees contribute to the feeling of escapism...
owner  Malayan Sdn Bhd, subsidiary of
Fusang's Group, public listed company
(Ting Kiang)
location  IB Sultan Ismail, Kuala Lumpur,
Malaysia (Kuala Lumpur's "Golden Triangle
Area")
latitude  3° N
nos of storeys  27 storeys
(including 1/2-level basement)
date start  1992 (June)
completion date  1996 (June)
areas
Total net area  17,092 sq m
Service area  5,272 sq m
Gross area  22,371 sq m
Carpark (334 bays)  13,121 sq m
Total built-up area  57,863 sq m
site area  2,982 sq m
plot ratio  1.75

design features
• The typical office floor in this 'water-
thin' tall building is to be column-free for a marketing requirement of the client. To enable this, structural cross bracing is
provided at the mid-columns of the east and west facades.
• Vertical planting steps up diagonally along the north face of the building up to the roof-terrace at the top of building.
• A system of balconies and terraces are located on the hot
west facade.
• The core, which consists of the lift lobby, stairways and
bathrooms, has natural ventilation and natural lighting.
• A curved lobby glazed curtain-wall on the north face gives
an uninterrupted view of the distant hills (in Ampang).
As this facade does not receive direct solar radiation, its
sunshade-free elevation becomes a form of geographical
indication of the northerly direction.
• The east and west glazing of the building are recessed
from the structure to sun-shading.
• The escape staircase is an 'open-to-the-sky' staircase.
• The main staircase is naturally ventilated.
• The lobbies are naturally ventilated.
• The east wall has balconies as sun-shading.
• The lift lobbies are partially naturally ventilated.
• The ground floor lobby is naturally ventilated.

structural system
• Replaced concrete structural frame
with prestressed beams, brick-in-fill

external skin
• Laminated floor glass
• Solid aluminium cladding

roofing
• RC slab on cool terrace

finishes
• Coating on lobby floor and walls
• Glass to entrance canopy
• Haste and paper to internal walls
• Ceramic tiles to wet areas
• Mineral fibre board to office ceilings
• Ethanol plaster in lobby ceilings
Attention to detail

Detailing is often overlooked in high-rise building throughout the major cities of South-East Asia. Yeang's attention to quality materials and construction is therefore what distinguishes most of his buildings from their neighbours. The naturally ventilated lobby immediately gives visitors the impression of a 'quality' building. A structural glazed wall on the north side reveals the security room, traditionally hidden from view. A bank of television screens and flashing lights contribute to the hi-tech image. Opposite the security room, sand-blasted glass "fish-scales", secured by steel bolts, "float" above the elevator doors. Looking out of the lobby the glass theme is continued with a transparent glass entrance canopy, through which natural lights are filtered, and reflected on the granite-clad floor and walls.

Inside the elevators, more frosted glass - illuminated from the floor up - and curved perforated metal screens lighten an otherwise oppressive space. On the ceilings of the corridors running the length of the fifteen office floors, elliptical recesses house light fittings with suspended frosted glass discs. Each major office door is fitted with a sophisticated Philippe Stark designed door handle.

... the glass-dominated lobby, with structural glass wall screening the security room, and glass "fish scales" floating above the elevator doors ...
So how do the design interventions...
Casa Del Sol stands relatively alone amongst Yeang’s bioclimatic projects, in that it is essentially a tall slab, and not a point-block skyscraper in the generic sense. Conceived as a semi-circular form, the building is a pure product of the sun-path. The project includes 160 residential units of accommodation together with a communal clubhouse and swimming pool.

The overall design is dominated by two key issues – the protection of the residential accommodation by a western band of circulation galleries that are separated by an air-gap from the main structure, and the provision of eastern facing views from the apartments to the valley setting.

Hence, the naturally ventilated, single-loaded circulation acts as a massive buffer to the hot west afternoon sun, and assists the cross-ventilation of the apartments themselves. The building includes planted and terraced skycourts that are spatially interconnected, stepping outwards from the centre of the building in a diagonal formation. Where they occur, these external spaces not only provide natural light and ventilation opportunities for specific apartments, but also contribute to the comfort conditions of adjoining residential spaces.

In addition, the major lift-lobby and staircase is located centrally in the semi-circular form, and again is a naturally lit and ventilated open assembly.
casa del sol apartments
plan in relation to wind-rose

annual summary of wind, 24 hrs
Source: Kuala Lumpur International Airport
Subang 1968-1993
Plaza Atrium (1986) and Menara Mesiniaga (1992) are both signal projects that mark key points of development and change in Yeang’s bioclimatic series. Similarly, the Hitechniaga Tower signals a further development which includes both the Shanghai Armoury Tower (1997) and the EDIT Exposition Tower (1998) – a new generation of highly expressive and innovative forms, which both further the evolution of an ecological aesthetic and architecture and exemplify Yeang’s proposition for a vertical urbanism.

Essentially, the Hitechniaga project reflects Yeang’s progression beyond a strict interpretation of the volumetric brief, to a point where he begins to expand the narrative of the form into an expressive dimension. This tendency is to continue with greater elaboration, into his subsequent works.

At first sight, the vertical clustering of the tower form, set against a rising backbone of vertical circulation and service space, recalls in passing the Japanese metabolist works of architects such as Kurokawa from the 1960s. But, this formal analogy is superficial and belies the more serious intention of Yeang’s fluid manipulation of vertical sparsity. The overall form is composed in two distinct parts, a seven-storey base of car-parking floor-planes and a sub-tower of training rooms and auditorium. Above this rises a series of occupied levels for the activities of the computer and software company that the tower houses. These upper levels are dramatically sliced open by major skycourts at levels 10 and 13, with extensive landscaping. Above this, the presentation and convention floor at level 16 is joined to the Hitechniaga Management at levels 17, 18 and 19 by an eastern flank of circulatory ramps, that are additional to elevators and stairs on the vertical western face. This is one of the first instances of Yeang’s incorporation of high-level pedestrian ramps, into the spatial movement pattern of the tower itself.

Both the eastward flank of ramps and the service core towers on the westward face provide part of the natural bioclimatic shielding on the hot solar sides – signal features of Yeang’s low-energy architecture. At the same time, the skycourts and linked terraces provide ‘ventilating-zones’ and external release for occupants throughout the higher levels.

In addition, a series of perforated-metal ‘shields’ are included, as outriggers to the main form, to sun-shade the building. But, in this case, both the scale and curvilinear scallop-shaping of these elements extends far beyond mere function and mark a point in Yeang’s formal articulation of the bioclimatic tower aesthetic. At one and the same time, these mechanisms are both solar-defensive and demonstrative. Taken together with the highly articulated form, the architecture assumes a ‘warrior-like stance’, crowned at the tower’s summit by...
Kuala Lumpur, Malaysia

Hitechniaga Sendiman Berhad
location: Sri Hartamas, Kuala Lumpur, Malaysia
latitude: 3°N
nos of storeys: 19 storeys
date start: pending
areas: Nett area 6,374 sq m
Gross area 8,623 sq m
site area: 1,308 sq m
plot ratio: 1:6:6

design features: The site is located 20 minutes from the city centre of Kuala Lumpur. The client wanted a distinctive corporate HQ building to house his company’s products (computers and software). The site is at a prominent corner lot, adjoining a series of clusters of four-storey shop-offices (to be built). The proposed tower on this site is 19 storeys and will contain spaces for reception and computer data centre at the ground floor at Level 1. At Levels 2 to 6 are meeting rooms and an auditorium. These are also accessible by a separate stair (away from the main tower lifts). Above this are 14 floors of office space. The features of the building are:

- Bioclimatic low-energy features such as all the lobbies, staircases and toilets have natural sunlight and ventilation making the building low-energy and safe to use (ie naturally lit stairs and lobbies in the event of power failure or other emergencies) and also to operate
- Skylights and ventilating zones are located throughout the upper floors of the building. These are linked by additional staircases and ramps to increase accessibility
- Perforated-metal shields are used to shade the building to shape and add form to the building.

by further shielding devices, developed from the earlier principles of Menara Mesiniaga.

Although Hitechniaga, as yet, remains as a project it decisively fulfils two central purposes: first, the tower itself provides exactly the forward-looking imagery demanded by the client, for a distinctive corporate HQ reflecting the nature of an innovative computer and software company, based in Kuala Lumpur, within an emergent corporate zone. Next and finally, it remains as a signal point of development in Yeang’s pursuit of the ‘heart’ of the deal combination of elements, within the composition of the biomimetic skyscraper.

In the latter respect, Hitechniaga stands on the entry threshold to a whole range of further projects that Yeang has undertaken in the following years beyond 1995-97.
The predominantly residential apartment, detail of the MBf Tower, and its potential for separation.

The tower's main idea is to create a clear expression of modernism, abstract and vertical landscaping.

The concept is to place the building on the western edge and to position it in a way that it appears to be floating. The design process and the decision on the building's distinct form and the material and the finish of the facade were derived from the tower's context with large residential areas and the tree canopy outside. The whole tower is seen as a grid of 36 square towers linked by a system of roofs and the tower through a white grid of the panoramic view, to the residents' view of the city.

The tower's design is inspired by the traditional housing, the square towers, and the layout of the residential areas.

The project's success is measured by the verticality and the energy efficiency of the design.
The residential tower is oriented from north to south, with the residential areas located on the line closest to the east-west axis present within the arrangement. The western residential areas face deep overhanging terraces, with planting, to create natural shading.

The residential plan has four apartments at each floor level, on both the north and south edges. These are separated by a central area of core galleries, elevators cores and stairs, etc. In turn, all these elements are further separated with floor slits and gaps, both horizontally and vertically, in addition. The upper levels of the tower have generous, two-story, sky-court cut-out openings, which penetrate the entire core. These together, the manifestation of the articulation of elements in both plan and section creates a flowing three-dimensional space, which is laden with cool, cross-ventilation channels, ensuring the thermal load of both circulation and apartments alike.

The landscape is supported by a vertical landscape, which provides skylights, terraces and planters with a profusion of nature and natural shading.

To experience the openness and outward prospect of the residential plan is a memorable and rare event - one that is further enhanced to be even more when one views the sea and the ocean.

After being one of the most successful projects, while its image is hermetic, we use and for the occupants, it offers a utopian environment and a sublime sense of elevated sanctuary.
Sir John Betjeman's A History of Architecture and the Future (1996). The architect's 'city of tomorrow' is not exemplified by the high-tech image of the 1990s. The image of a residential and mixed-use building is Euro-garden. The courtyard is designed by a rational architect who presents the building as a modular, pre-fabricated structure. The design is based on a free and creative approach.
Yeang's earliest realised projects for a landmark commercial building, designed for sale and rental. Standing on the threshold of Yeang's bioclimatic skyscrapers, the incised heavy white masonry form is not typical of Yeang's mature architectural projects which generally incorporate lightweight demountable cladding.

The lower floors incorporate space for retail and bank use, with integrated car parking. Office space occurs from the second floor upwards.

The foreshortened triangular plan form is a direct function of the restricted site with the major shielding clusters of stars, lifts and restrooms located on the predominant north and south faces, again not typical of Yeang's later classic bioclimatic projects. The resultant exposed west, and particularly the south-eastern facades, are therefore heavily clad masonry profiles, with deeply incised horizontal glazing bands.
But the project is precisely inflected by a single passive-mode environmental device - a soaring naturally ventilated atrium, serving the office floors and rising on the north-eastern sector of the overall plan. The cascading, planted balconies of the office spaces all relate to this crucial interstitial volume, which unlike conventional office towers of this period, is open to the air and acts as a giant wind-scoop. Although, in this project, the wind-scoop idea appears incidental, in fact it foreshadows Yeang’s later use of wind-walls, such as UMMOTower in Penang, and other later projects, which are more sophisticated in their use of natural ventilated spaces.

Of Plaza Atrium, Yeang has made this statement:

“...Unlike most atriums, this space is not located within the building envelope but in the transitional space between the interior and exterior. The atrium is capped by a louvered roof using Z-profile louvres. This filters out rain while allowing hot air from within the atrium to flow out and diffused sunlight to enter.

The entire atrium acts as a giant wind-scoop, capturing airflow high up on the building and enabling wind to enter the typical upper floors, controlled by the sliding doors of the terraces facing the space itself. The office floors facing the atrium are setback and lined with landscaped terraces with views down into the atrium space.”

Thus, in this among Yeang’s commercial bioclimatic skyscrapers, the modus of passive-mode intervention is evidenced, which marks the overall form of the architecture.
The Plaza Atum (1983), in the capital's Golden Triangle district, by Hamzah and Yeang, is one of a series of experiments by its architects to develop high-rise "bioclimatic" architecture appropriate to the tropics, based on rational principles of climate control. Partially inspired by shophouse arcades, the upper floors on one corner of the Plaza Atum are stepped back under a canopy roof, leaving the corner exposed like a portion of a giant arcade. The architects' highly original approach is best exemplified by the Menara Mesinaga Tower (1992), an office tower situated near Kuala Lumpur International Airport, and the MBF Tower (1994), a residential and mixed-use building in Georgetown, Penang.
The design involves the integration of a traditional setting with modern elements. The plot ratio is critical in determining the building's footprint. The building's orientation and the plot's bay allow for optimal natural light and ventilation. The design aims to promote sustainability and energy efficiency. The traditional elements are designed to complement the modern structures, creating a harmonious blend.
Singularity: Keang's most significant theoretical project of the mid-1960s, the Tokyo-Aura Tower is an experimental design that allowed the architect to investigate and refine ideas and materials that had been occurring within his ongoing practice of tall buildings.

Essentially, the design can be summarized as the architecture—the new floating core. Although the concept may bear some resemblance to the diagram of Menara Masjid, its otherwise a completely new organic invention and combination of many of the developed versions of Keang's future projects.

The designed plan-form is oriented with the stacking mass circulation cores on the outer east and west faces. These are the rotating floor slabs, which shift position on alternate floor levels. Keang has described these planes as accelerating in a circular manner—an abstracted rounded triangular element, possibly assembled in a true grid of columns. In looking at how this first concept structure appears to resemble earlier work and a subsequent design development by a triangular three-axis mass circulation system with a further central mass that shares circulation and support elements supporting the floor planes—the whole form being enhanced by tension-rows and linear service tracks.

While the initial concept is a reinstallation of the engineering tools of the 20th century, these can be done using new conventional engineering principles that incorporate fractal geometries and the idea of a more sophisticated and integrated structure that in turn would support the overall spatial constructs.
However, as with all great ideas, all these supporting systems ultimately serve a new architectural conception. Overriding everything else, in this case, is the central principle of spiralling vertical landscape.

Yeung's evocative and compelling sketches describe the attributes of the project much more succinctly than words, but these include:

- Stepped terraces and planters — with intermediate and roof gardens, creating a varied and accessible composition of commercial, office and residential accommodation.
- Extensions of the building and the sky court principles.
- Wind flues to bring wind ventilation to the inner parts of the building with adjustable dampers.
- Rotating, moveable sun shades and wind shields.
- Service blocks that spiral up the building to carry mobile cherry-picker devices that care for the prolific planting spiral. Gathered together, all these ideas and the benefits they bestow to the occupant — such as the natural shading and cooling resultant from the planting to the atrial and occupied inner spaces — are also the emergent signals of Yeung's pursuit of an ecological architecture that is both balanced and all encompassing. All that is missing from this project is the later incorporation of informal circulatory pedestrian ramps and linkages between the host of levels.

But, in every other respect the Tokyo-Nara Tower is Ken Yeung's first major exposition of his concept of Vertical Urbanism. In this singular respect, it remains significant.

**Tokyo-Nara, Japan**

**Owner:** Naniwado Municipal Office
**Location:** Urban site between Tokyo and Nara
**Latitude:** 35° 42’N
**Nots of Storeys:** 160 storeys (approx. 850 m)
**Areas:** Gross area 4,828,160 sq m
**Total Net Area:** 4,661,603 sq m
**Total Built-up Area:** 4,828,160 sq m
**Plot Ratio:** 1:40

**Design Features**

- A conceptual project, prepared for the World Architecture Exhibition in Nara, Japan in 1983, the idea for the strictly rectangular skyscraper the lower floor plan makes many of the theoretical steps anticipated by Yeung, and represents a significant stage in their ongoing research into the nature and evolution of tall buildings. The city behind its concept can be summarised as follows:
  - Most visually apparent is the vertical landscaping — spiralling round through and within the built form.
  - The element performs many important functions:
    - The vertical foliage acts to cool the building, both by means of shading and by chemical photo cooling.
    - The bringing of fresh and cool air allows careful planting and control of movements within the built structure.
    - The mass of planting relative to the built structure is a very noticeable, thereby ensuring that it is not a simple, but a balanced and balanced building.
  - The maintenance of the vertical landscaping, as well as the system of external features, plumbing and cladding panels is ensured by automated mechanical devices. These devices, combined in the form of multiple multiple 'cherry-pickers', maintain an internal circulation of refined and controlled ventilation and ventilation / cooling systems.
    - A constantly changing atrium space, calculated by the internal, external court and private garden.
  - Located at regular intervals, the internal courtyards provide inhabitants with an environmentally sound break in the built structure. These green spaces, suspended high above the city, would benefit from fresh air, and be constantly maintained as part of the building's internal system. They would act as a Tokyo-Nara Tower's lungs, breathing life into the floor above and below, via the atria.
  - The communication shaft-tower set in the upper floors of the building are used for satellite links and other services appropriate to advancing global village communications.
  - The atrial spaces, leading within Tokyo-Nara Tower, are the atrial routes by which fresh air enters. Terraces and courts, looking down on each other, fed by channels of through flow, are semi-enclosed and semi-enclosed. The atrial network bridged by stairways and ramps by stairs, constitute a maximum of Kinetic within the tower and with the spaces opened to the environment.
  - The service cores of the building are orientated according to solar conditions.
  - Laid along the East-West axis, these lift and service cores are designed to use the potential of roof gardens. The lower floors, on the north south axis are left open to clear glassing and atrial views.
  - The shading and glazing systems are orientated to use gain. These are used for the heating of the building along the east-west axis are made with thin and perforated metal which is a perihelion material for reflective and translucent glass. The south north axis can be orientated by roof garden.
  - Other methods of control are also used, including positive ventilation and ventilation / cooling systems.
  - Large volumes of fresh air are used to cool the building, both by means of shading and by chemical photo cooling.
  - The vertical foliage acts to cool the building, both by means of shading and by chemical photo cooling.
  - The bringing of fresh and cool air allows careful planting and control of movements within the built structure.
  - The mass of planting relative to the built structure is a very noticeable, thereby ensuring that it is not a simple, but a balanced and balanced building.

This is a new vision of architecture, both in its form and in its function. It is a project conceived for the specific context of the Tokyo-Nara region, and in this context it is a visionary and innovative project. It is a project that addresses the issues of sustainability and environmental responsibility in a way that is both innovative and innovative. It is a project that is a statement of intent, and a statement of what is possible. It is a project that is a testament to the power of vision and the power of imagination.
apartment floor

communal facilities floor

cellular-honeycomb structural frame
cherry-pick or service platform
secondary structure
tension rod
primary structure

office floor

hotel floor

SUPPORT RIBS TO BEING TO BE EXTEND TO BASE POINTS OF THE BUILDING WITH ADJUSTABLE DAMPERS

SERVICE TRUCK THAT SLIPARLS UP

RODATING OVERALL SUN SHADES AND SHIELD

BASED INPLANTED
As a general comment, the floor plans are very diverse and the tower is considered as an 8-2-storey box. The tower is ventilated during the warmer months. The horizontal stresses due to horizontal wind loads act on the tower towards the base, reducing with height. The horizontal sway due to horizontal wind loads is minimal at the base, reducing with height. The horizontal deflection due to horizontal wind loads is the highest point from the supports at the ground.
The skyscraper should not be a stack of homogenous concrete plates.

DNA tower analogous to the cellular structure of the needle of the porcupine.

The anthill as a bioclimatic skyscraper.

Rotated magazine stack analogy.
Taken together with Plaza Atrium, the IBM Plaza is another version of Yeang’s early white-cubic towers and atypical of his later, mature designs. It is however infused with some basic characteristics of the bioclimatic series, notably orientation, solar shielding, shading and facade planting. The complex also has an urbanistic interface and incorporates an early glimpse of Yeang’s ideas for a vertical urbanism — in this case a fragment — in the form of a mid-level breezeway floor, and the high-level shaded roof terraces.

The design was intended to reflect the progressive nature of the company for whom it was commissioned, and is composed of two forms — the tower itself, which includes both car-parking and office space, and a two storey restaurant/food court, which is linked by a curvilinear bridge. This complex is contained in a ground level plaza, surrounded by paved, pedestrian roads related to the grid of the adjoining shophouses.

The overall plan form of the tower responds to two geometries — that of the skewed sun path and the regular site grid of site context and roads. The tower plan is essentially a nine-bay square, orientated north-south relative to sunpath, with the outboard service cores on the hot east and west sides, providing solar shading and aligning with the site geometry. Two additional features relate to the tropical climate: at ground level the lift lobby is open and naturally ventilated, revealing the pilasters and signalling the external plaza. Equally, the top levels of the tower are celebrated by a crowning open-louvre sun-filter, whose pitched section form is intended to evoke the memory of the traditional Malay house.
Solcmor, Malaysia

IBM Plaza

These two elements of openness, at the base and the crown of the tower, are linked by vertical facade planting. The local landscaping and planting are introduced in an innovative vertical escalating system of planter-boxes and trellises which start from a mound at the ground floor and rise diagonally up the face of the building. At mid-level, these planters traverse horizontally across the breeze-way floor - a Hawkers’ Centre - and escalate again diagonally up the other face of the building to the roof terraces.

The extensive geometrical feature of diagonally inflected vertical landscaping, which suggests a spiral of natural development, is further developed in Yeang’s more sophisticated projects such as the Nara Tower and others.

In this case, the diagonal vertical landscaping is counterbalanced by the overhanging floor spandrels, producing deep recesses and sunshading. At the upper levels the floors and spandrels are skewed and extended outwards in a reversed stepped form, which provides additional wedge-shaped projections and further shading.

As well as having a climatic reference and purpose, these shifts in the form of the overall design are intended to announce a move away from the conventional modernist office slab-tower, and suggest a new more responsive alternative.

While IBM Plaza is not a central project in Yeang’s overall postclimatic series, it is nevertheless part of the general evolution of the type, incorporating the principles of orientation, shading, and elements of natural ventilation.

Owner: TFBI Development Sdn Bhd
Location: Taman Tun Dr Ismail, Kuala Lumpur, Malaysia
Latitude: 3°3’N
No. of storeys: 24 storeys
Date start: 1983
Completion date: 1985
Areas:
Total built-up area (excl. carpark) 26,057 sq m
Total built-up area (incl. carpark) 41,885 sq m
Carpark area 15,828 sq m
Hawker’s centre 52 sq m
Site area 8,096 sq m
Plot ratio 14:1
Design features:
- The building consists of a core tower linked by a cantilever bridge to a two-storey restaurant/food-court tower block. The two forms are punctuated in a plaza in which the surrounding roads are pedestrianised and paved to meet the adjoining shopfronts.
- Two geometries are recognised: one of the sun (the sun’s path) and the other of the site in relation to the road (or conventional geometry). The typical floor is orientated aligning north and south in relation to the sun’s path and geometry.
- The spandrels (core boxes, stairs and terraces) are on the hot sides of the tower (i.e., the east side and the west side) and follow the geometry of the site (by this configuration the layout of the built-forms respond to the local hot-humid tropical climate in its planning and disposition.
- The top of the tower is pitched to be reminiscent of the traditional vernacular houseform. The local landscaping and planting are introduced uniquely into this tall building in an innovative vertical escalating system of planter boxes. These rise diagonally up the face of the building. Then at mid-level, the planters traverse across the floor and escalate again up the other face of the building to the roof terraces.
- The ground-floor entrance lift lobby that leads to the plaza is opened to the outside and is naturally ventilated. The upper floors are extended in an asymmetrical pattern resulting in the wedge-shaped projection in the upper floors.
- Generated in overall form which is non-regular and thereby deviates from the purist modernist slab-form for the tower.

Programmes:
- To provide a landmark and headquarter building for the developers of Taman Tun Dr Ismail that reflects the contemporary progressive nature of the development company and at the same time, to retain a regional character in the architecture. Maximum plot ratio of 14:1 to be utilised. The major part of the building is to be leased to IBM Corporation.

Structural system:
- Reinforced concrete frame
- Concrete slabs, trusses, and beams
- Concrete elevator shaft construction
- basement retaining walls

External skin:
- Precast tiled sunshading
- Tinted glazing with half-clear panel
- Concrete coping to external wall
- Precast glass-floored concrete louver, void over roof floor

Interior:
- Bird’s-eye, granite, plaster ceilings
- Suspended acoustical ceiling, concrete floor with carpets
- Vinyl plastic strips

Mechanical system:
- For basement carpark for
- Tempered air ventilation system
- for office/air-conditioning system

Detail of planter box with gravity-fed watering and nutrients feed system
Menara Boustead is essentially a transitional work within Yeang's early series of bioclimatic skyscrapers, standing between the initial white-cubic towers such as Plaza Atrium (1981) and the definitive silver-cylindrical Menara Mesiniaga (1989).

Although the tower, as a basic commission, is a corporate headquarters building incorporating just office space and car-parking, the intention of the design was to go beyond the conventions of stacked office-floor types. The project therefore includes several important innovations that reoccur in Yeang's future works — principally these are the introduction of skycourts, solar shielding with service cores, and rain and heat-check aluminium skin.

The plan-form is based on a square, with protrusions, and encircled in part by an outer layer. This formation allows the introduction of both skycourts and terraces in the outer corners of the plan, and characteristically marks the overall form of the tower throughout its height. These external transitional spaces perform several environmental functions: the balconies incorporate irrigated planting and landscaping and the sun-shading they provide allows full-height openable glazing, which contributes both natural-light and ventilation to the inner office spaces, enhancing user quality and comfort conditions. The skycourt terraces also provide a flexible zone for additional services, such as supplementary air-conditioning units.

The dominant effect of the planted terraces, which incise the partial-cylindrical form, is to striate the whole precise mass and festoon its surface with rich, colourful planting layers. Given its height and the intensified urban location, this comes as a relief. The skycourt, as a device, is an element that is developed significantly in Yeang's future designs, but the basic combined principles of deep facade recesses, balcony terraces, planters and heat-sink cladding and overall solar configuration, are all grounded in the Boustead design.
Kuala Lumpur, Malaysia

Boustead

Owner: Boustead Holdings Berhad
Location: Jalan Raja Chulan, Kuala Lumpur, Malaysia
Latitude: 3.2°N
Nos. of stories: 31 stories
Date start: Phase I (first 16 floors of office building and first 8 floors of carpark building) 1986 (May)
Phase II (11th to roof of office building, basement level, 9th to roof of carpark annex) 1986 (November)
Completion date: 1986
Areas: Total built-up area 29,840 sq m
Carpark area 15,630 sq m
Nos. of carpark bays: 400 bays
Site area: 1,920 sq m
Plot ratio: 1.697

Design Features:

1. The objective was to design the office building to be more than mere space of several enclosed concrete bays stacked in the air. Here in this building are 'corner terraces' on each floor. These terraces are located at all corners of the building, providing a unique design element.
2. The vertical plan layout exemplifies the ideas for a typical high-rise office building.
3. Lift cores and toilets are located on the double-sides of the building, e.g. on the West and on the East.
4. Lift lobbies have natural sunlight and ventilation.
5. All windows are sun-shading.
6. The building is designed to accommodate a total of 530 cars of which a 530-car park is provided at ground level.

Materials:

- Natural stone and granite for floor and wall cladding, marble, terrazzo, wood, etc.
- Structural columns, slabs and staircases are reinforced concrete elements.

Mechanical System:

- The air conditioning system is a centralised fan coil system with a central air handling unit. Air is supplied to individual offices through a network of ducts.
**Marketing Features**

- **Design Features**
  - Feature 1: Skylights for sun-shading to office area to reduce energy consumption
  - Feature 2: Executive suites with provision for executive washrooms (plumbing & sanitary units)
  - Feature 3: Workmanship varies
  - Feature 4: Toilet/laundry area on west front to minimize solar insulation into office for single tenancy
  - Feature 5: High speed lifts to minimize waiting time (35-31 sets)
  - Feature 6: View out from lift lobby
  - Feature 7: Column-free clear office floor space for flexible partitioning and sub-division of space
  - Feature 8: Articulated corners to give panoramic view to office
  - Feature 9: Main exit capable of expansion to cater for increase in loading areas for future computer rooms or conference room
  - Feature 10: North-south orientation of floor to reduce solar insulation and energy consumption

**Floor Utilisation Efficiency**

<table>
<thead>
<tr>
<th>Zone</th>
<th>Net Office Space</th>
<th>Useful Office Space</th>
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<tbody>
<tr>
<td>A</td>
<td>8425</td>
<td>82.3%</td>
</tr>
<tr>
<td>B</td>
<td>600</td>
<td>5.5%</td>
</tr>
<tr>
<td>C</td>
<td>1970</td>
<td>17.9%</td>
</tr>
<tr>
<td>Total</td>
<td>10995</td>
<td>100%</td>
</tr>
</tbody>
</table>

**Option Studies of Orientation Options**

**Option 1**
- **OTTV** = 36.40 W/m²
- **OTTV** = 35.57 W/m²
- **OTTV** = 51.04 W/m²
- **OTTV** = 74.83 W/m²
- **Total OTTV** = 30.49 W/m² (less 40%)

**Option 2**
- **OTTV** = 11.96 W/m²
- **OTTV** = 33.36 W/m²
- **OTTV** = 41.63 W/m²
- **OTTV** = 47.92 W/m²
- **Total OTTV** = 78.94 W/m² (less 64%)

**Option 3**
- **OTTV** = 41.23 W/m²
- **OTTV** = 45.07 W/m²
- **OTTV** = 52.71 W/m²
- **OTTV** = 65.17 W/m²
- **Total OTTV** = 51.57 W/m² (less 100%)

**Assumptions**
- Shading coefficient of glass = 0.80
- Absorptivity of opaque wall = 0.50
- "U" value of wall = 0.1969
main entrance to the exhibition gallery

main retail block

service entrance
The BATC Tower is a signature high-rise office development, which stands at the centre of a massive proposal for Kuala Lumpur.

At the level of urban design, the overall project is one of the largest assemblies that Yeang has ever proposed. The scheme, for 47 acres of landscaped park space, is serviced by a central range of public plazas, boulevard walkways and public car access routes, together with a centralised station for the LRT System, which is situated at the junction between the retail, commercial and university facilities.

In addition to the BATC Tower, the development includes five 30-storey office towers all designed within the principles of the bioclimatic agenda and incorporating Yeang's ideas for vertical urbanism.

In overall content, this project for the Business and Advanced Technology Centre (BATC) and a Branch of UTM (Universiti Teknologi Malaysia) will incorporate facilities for a School of Advanced Education programmes and an integrated research and development complex for some 20 institutes and centres. The proposal has resonances with similar developments in major universities, such as Cambridge (UK), and other locations on a global basis. Together with this, Yeang has proposed a high-tech office park; convention and exposition centres; a multimedia and IT college; mega-theme mall for retail and entertainment; major outdoor public spaces with cultural uses; residential accommodation for students, postgraduates and academic researchers; a four-star hotel for visitors, tourists and local residents with business centres and facilities; and a public park and boulevard that runs throughout the development project. The central theme is that of a landscaped setting and a sheltered traffic-free environment.

The central spine of the project running north to south, is essentially surrounded by the major higher forms, that include the BATC Tower on the western side.
In itself, the BATC signature Tower stands amongst the most significant of Yeang's bioclimatic skyscraper proposals unified within this major form are two major principles: first the inclusion of vertically linked, continuous landscaping applied to terraced sky courts; and second the application of vertical urbanism, which Yeang describes as 'places-in-the-sky' - the amenities of a city, vertically distributed throughout the tower-form. While this has become a recurrent, objective proposition in Yeang's work, the BATC Tower is one of the richest designs that he has composed in this respect. The design is further strengthened by the extensive facilities of the related plaza and Exposition Centre, which share a similar climatic openness.

In reviewing the BATC Tower floor plans, over some 60 or more levels, several features are immediately clear. The lower levels are marked by the entrances and transportation links, and the higher levels by extensive linked tenant areas, interspersed with special functions, sky courts and public spaces. Throughout the vertical arrangement, linkages in the form of pedestrian ramps are included at intervals, augmenting the elevator systems and facilitating a flowing spatiality of movement.

The special functions include restaurants at various upward locations, an E-FX Gallery, and a Digital Output Center. These are supported by sky plazas, outdoor public space, internal atria and continuous vertical gardens. The whole assembly is capped by a planar wing-form roof, which shelters high-level observation decks.

The skyscraper has four refuge zones distributed vertically, which define the sets of tenant floors and public uses that are incorporated. At the lower levels gymnasium, swimming pool and health center are accompanied by an auditorium and family center. Similarly at the higher levels, seminar rooms, computer and production suites are mixed together with tenant spaces, sky lounges and an all-digital public amphitheatre. These groupings serve merely as examples of the extensive range of provision and occupancy that Yeang has induced within the rising vertical framework - a continuously upward flowing urbanistic spatiality.

Characteristically, the hot eastern tower facade is solar protected by a rising range of services and elevators, with the longest elevations facing south and north. The canted semi-rectilinear plan is sliced open at intervals to allow airflow ventilation to both offices and public spaces. Together with the sky courts, fabric engineering and Integrated Building Management Systems (which control internal conditions by monitoring the immediate external surroundings through environmental sensors located on the roof), the entire building is part of a bioclimatic entity, which applies to the whole project and site.

Although it remains as a project to date, the BATC Tower and its associated master-plan summarise an important stage in Yeang's work, seen overall, and many of the innovations contribute to its future development.
The Al-Hilali Complex for Kuwait City is a large mixed-use development. A multi-purpose plaza, retail complex, boutique hotel and city club form a massive plinth, together with a public plaza and a low multi-storey car-park structure with a landscaped roof, forming a mini golf course. This extensive base of facilities forms a distinctive setting for the 20-storey office tower.

The design solution that Yeang has composed is based upon an extensive 'Environmental Design Brief', providing all members of the design team consultants with a clear set of objectives. As with all of Yeang's green skyscraper projects, the emphasis is on integration of all systems in order to establish an environmentally and ecologically responsive design, whose bioclimatic content and performance relates directly to the site in Kuwait. The design is therefore envisioned both as an exemplar of Yeang's ecological architecture, and as an outstanding landmark in terms of urbanism and the city.
Yeang's environmental design brief incorporates much of his green design theory, and provides a thorough, comprehensive basis for the achievement of a complex of sustainable intensive buildings, across the whole spectrum of design issues involved. This ranges from the general considerations of transitional spaces through semi-enclosed to enclosed spaces, related to the whole project, and the detailed analysis of building configuration and its relationship with the ambient environment and the resolution of this in, for example, the design of the office tower.

A major instance of transitional space underpins the design of the Central Plaza within the shopping complex. This space, intended for multi-seasonal activities and foodcourts includes major ramps for peripheral pedestrian circulation. The key element is an operable glass roof, a layered transparent covering, which opens or shuts depending on climatic conditions and the seasons of the year. For example, the roof is fully closed in hot summer months acting as a shading device, and open during other seasons. It can also be opened at night, for heat flushing of the space.

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north tower facade

A fine wall with sun-shading for maximum solar protection at hot west facade

south west tower facade

East face is to have a double-layered flue wall as a ventilating space

Solar shading throughout the east facade will provide sufficient protection against morning sun

north tower facade

Photovoltaic cells are located at south facade to maximize collection of passive solar energy

south tower facade
Similarly, the office tower incorporates a series of skycourts as transitional spaces and in accord with Yeang's design principles for buffer zones between interior and exterior spaces, which also provide shading and locations for planted and landscaped terraces.

The low-rise retail buildings incorporate a series of vertical shafts, or chimneys, which permit air from the lower spaces to exhaust above the roof level - a system similar to the 'wind-towers' of the Dubai Towers project.

What emerges overall is that Yeang is defining very clearly the range of space types within a massive construct, identifying those which benefit from passive principles and then using a range of means to reduce energy consumption and provide sustainability to enclosed serviced spaces.

A prime example of this integrated, concentrated design methodology is evidenced in the enclosure options of the office tower and its shell, and the adaptation of the building configuration to its local environment, the Al-Hilali site being 29.30° north of the equator.

The office tower is related to the solar-path, with the shaped plan-form located on a west-east axis in order to reduce solar impact on the longer sides of the tower. The key element of the plan is the linear grouping of service cores - lifts, stairs and service spaces, on the southern side of the form, in order to act as a solar-buffer, or shield-wall on the hot face. Each facade is considered in detail, in order to reduce solar-heat gain to the interior and to provide opportunities for fresh-air ventilation - both as an acoustic barrier and to augment the expression of Yeang's green skyscraper aesthetic.

In this connection, both east and west facades incorporate a double layered flue-wall as a ventilating space, with a canted section whose volume increases with height. This arrangement exhausts air as ventilation through the facade construction, and at the same time minimises solar heat gain, together with external sun-shading devices. Yeang has then explored the detailed ventilation facilities these facades offer, including the Coanda effect, which produces a stable and draught-free air movement within the interior space, together with natural and night ventilation, which exploits temperature extremes. In addition, the flue-wall protects the building in summer by ventilation and in winter, in a closed condition, as insulation.

In contrast, the north facade of the tower is a full-height glazed curtain-wall, and the protective south facade shield incorporates photovoltaic cells to maximise the collection of passive solar energy.

The overall organic form of the tower is shaped to induce natural ventilation and cooling - a basic of sustainable design. Without the tower floor-plans are marked by the inclusion of ramps connecting the floor levels, in addition to the elevators, and without a four-floor-high penthouse and roof gardens cap the summit of the north facade, with an oversailing helipad.

In the overall performance agenda, Yeang has again applied the criteria of embodied energy assessment, low-energy operation - for example by the use of 'thin'-plan floor plates - which reduce artificial lighting and optimise natural lighting, and the consideration of recycling of materials.
tenant occupancy options

- lower occupancy with ramp option
- lower occupancy without ramp

- single tenant
- double tenant
- triple tenant
- multiple tenant
As with all of Yeang’s projects, the crucial factor of the ecological design of the skyscraper is the act of balance between inorganic and organic content of the form – achieved by the incorporation of rich, extensive vertical landscaping. In this case, the vertical is augmented by the horizontal landscaping of the base.

This is yet another case, where the design, its objectives and criteria and their application, are documented in such a way that enables the client to understand and participate in the process and realisation of the total project.

Related to the context of Kuwait, Yeang has made specific the nature and qualities of his architecture that reach towards a sustainable future.
The building project is essentially that of an office tower with a linear central atrium, and an associated parking structure for cars. The lower levels include a major banking hall for the Hong Kong Bank, associated with main entrance and atrium space. Above the banking hall levels, there are parking structures all dedicated to banking business activities distributed on the east and west flanks of the atrium space. Below the main plaza level entrance at level 2, a lower recessed floor at level 1 contains communal facilities including recre gymnasium and canteen with a sunken garden terrace. This lower level also provides for general deliveries, a separate car delivery bay and the entrance to the car-parking structure.

Aside from the major double-height volume of the parking hall which dominates the main entrance area, the central atrium with its series of high-level interconnecting bridges, glazed elevator cars and escalator systems, is the principal spatial focus of the project. The major ground-level vistas through the atrium space is contained by a stepped range of garden terraces that recede beyond and serve to visually shield the car-parking structure.

Yeang's site analysis and design responses lead to a very direct and integrated solution. This process of assessment includes a geomancy analysis, which positions the preferred entry point and its angle and results in the main entrance, and the atrium itself. Next, the traffic and pedestrian routes of Petaling Jaya are summarised by a pedestrian zone related to the building, its vertical drop-off and the construction of the public promenade through the atrium. Finally, there are the studies of sun-path and wind-path, both of which have a major impact on the building design. In overall terms, the sun-shading devices screen both east and west surfaces of the double-glazed facades, shielding both morning and afternoon sun and resulting in a sophisticated studded form. The wind-path study is determined by the inclusion of major louver banks, on the vertical ends of the naturally ventilated atrium, capturing and channeling the cross-flow of both north-west and south winds. The atrium conditions provide both external and internal views for the surrounding offices, and skyrises are introduced on the outer faces of the upper floor levels.

The atrium is announced at the entrance by a major overhanging canopy and is partnered at high-level by a planar rooftop pavilion. Throughout the project, and particularly in the public plaza and rising levels of the public space, vegetation is used to create a pleasing environment and to soften the transition between the tower and associated parking - the hanging gardens descending from the car-parking roof.

What is evidenced here is the elegant simplicity that results from the direct application of Yeang's design principles - aspects of his green skyscraper agenda and the pursuit of a low-energy building response in the most commercial of circumstances.
Solongor, Malaysia

client: Hong Kong Bank Malaysia Bhd.
location: Petaling Jaya, Malaysia
latitude: 1.07°N
no. of storeys: 11 storeys + 1 mezzanine floor
date start: Design
completion date: Pending
areas:
  total gross area: 79,248 sq m
  total net area: 59,436 sq m
  car parking: 54,999 sq m
site area: 23,039 sq m
plot ratio: 15.2

design features:
- The building is configured as a tower block with two wings, separated by a central atrium space, with interconnected bridges, and an attached car-park block.
- The atrium is naturally lit and ventilated, and provides additional external views for the offices.
- The tower is wrapped in sun-shading louvres as a passive solar device.
- Vegetation is used to create a pleasant internal environment, and to soften the transition zones between the car-parking block and the tower. A stepped plante extends from the ground floor of the atrium up to the roof of the car-parking block, as a key design feature.

design responses:

- promenade analysis
  - response
  - pedestrian traffic
  - sun path
  - wind path

(hongkong bank tower)

(hongkong bank tower)
In-plant glazed ventilated wall with plane blinds (east and west elevation)

Double wall option (east and west elevation)

Light shelf and blinds with clear double glazing

Full-height glazed wall with light shelf

Full-height glazing with external adjustable blinds and perimeter coil units (east and west elevation)

Potential water conservation strategy

Full-height glazed wall with light shelf

Wind turbine system schematic

Wind turbine

Solar thermal panel system schematic

Water conservation strategy
atrium
(drawing by Noon Looi)

section of atrium showing landscaping
In certain key respects, the EDITT Tower is closely related to both the BATC Tower and particularly the Nagoya 2005 Tower, with the common themes being in the realm of vertical urbanism and exposition uses.

The Urban Redevelopment Authority of Singapore Competition for an Exposition Tower provided Yeang with a similar opportunity to the Nagoya project, but on a smaller scale and on a restricted corner site in the Singapore urban downtown of major commercial tower forms.

While meeting the client’s programme requirements for an exposition tower, including retail, exhibition spaces, auditoria and related facilities, Yeang used this as an integrated basis to demonstrate much of his agenda for an ecological architecture. The pursuit of this ideal, through his many projects, leads to the establishment of his comprehensive vision of the ‘green skyscraper’. The EDITT Tower is therefore significant as an exemplar of the ‘green skyscraper’ agenda which has a major impact on the design and the method of assembly, operation and future life as a reusable framework.

The nature of Yeang’s ecological design and its foundation of interconnectedness is explored in the introductory essay and the direct application of those principles is evidenced in the EDITT Tower more completely than in any previous project. It is therefore very much a part of Yeang’s evolution and the direct application of his thought, just as Menara Mesrshapl forms a benchmark project in the earlier bioclimatic skyscraper series.
The vegetation species selected for the building is based on the percentage of different indigenous plant materials in the area and an 'existential' analogy of the area. This ensures that the species used are ones which are not in competition with other species on the site and surroundings. The other factors considered in our selection of planting are: planting depth, light quality, degree of maintenance, access, orientation, wind, wall and panel-specific glazing actions.

**Design Features**

- **Response to the Site's Ecology**
  Ecological design starts with looking at the site's ecosystem and its potential adaptability. Any design that does not take these aspects into consideration is essentially not an ecological approach. A term such as 'responsive to the site as a response to an 'existential' analogy of the area.'
Yeang's first analysis is concerned with what he describes as a 'response to the site's ecology', carried out in relation to a 'hierarchy of ecosystems'. From this he concludes that the site is an urban 'zero culture' condition – 'a devastated ecosystem with little of its top soil, flora and fauna remaining.' His response lies not only in the rehabilitation of the site's organic mass, but in the introduction of planted facades and terraces which ramp upwards from the ground level to the summit of the tower, in a continuous spiral – a 'landscaped ramp'.

Detail recommendations are then given for the selection of appropriate planting species, based on a survey of the locality.

The concept of the continuous planted facades and terraces, itself, is integral to most of Yeang's projects, but in this case the vertical landscaping occupies an area equal to approximately half the usable area – an extraordinarily high proportion. Therefore the scale of landscaping provision, which is based on species that do not compete with those existing in the vicinity engendering diversity, and most importantly ensuring ambient cooling of the facades, coupled with the continuously shifting organic plan-form results in a tower that is literally a landscape-form.

Further studies that are applied to the design, and result in special elements of the architecture, include water-recycling and purification, sewage recycling, solar energy use, building materials recycling and reuse, natural ventilation and mixed-mode servicing, and an embodied energy and CO2 analysis. All of these studies form part of Yeang's ecological design agenda and are integral to the form-giving process, in the main.

For instance, the summit of the tower takes the form of a massive rainwater collector – a 'roof catchment pan', and is accompanied by facade-scallops to catch rainwater run-off – all part of a recycled grey-water system. Similarly batteries of photovoltaic panels contribute both to the façade architecture, and crucially to the reduction of electricity demand and cooling load. In analysing each system, a contribution is made to a sustainable architecture which has its own unique identity.

In addition to the vertical landscaping, two further aspects of the design content are noteworthy – these include 'Place Making' and 'Loose Fit'. In addition, the overall plan-form is configured with a solar-shielding wall curvature of elevators, stairs and services on the hot east face, and the design incorporates 'wind-walls' to assist both internal comfort conditions and that of the skycourts – developing the principles applied in the UMNO Tower. The plan arrangement is also deeply inflected by the extensive use of pedestrian ramps, which provide additional vertical linkage and form part of the expressive language of the architecture.

The ramp-systems are also an important element of Yeang's vertical urbanism strategy, in what he describes as a 'vertical extension of the street', these movement spaces are intended to be lined with street activities such as '... stalls, shops, cafes, performance spaces, viewing decks ...' through the first six major floor levels. The design also incorporates a 'views analysis', to ensure that upper-level occupants have the best of the surrounding vistas of the city.

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2. Ibid
3. Ibid
In this instance, Yeang has also applied a 'loose-fit' policy and has expected change of use of the tower to offices or apartments, over the building's life-span of 100 to 150 years. The implications of this are, for example, the occupation of 'sky courts' for office use, removable partitions and floors, and the use of 'mechanical jointing' of materials to enable future recovery and recycling.

What the building exemplifies is an early application of the more complex principles of Yeang's ecological design approach, and the increasing involvement of multi-disciplinary design teams contributing to comprehensive, interconnected assessment of all aspects of the site the architecture and its formation. At the same time, Yeang is raising the expectation and standards of the immediate future and the requirements of a genuine green architecture.

### Energy requirement for materials (GJ/tonne)

<table>
<thead>
<tr>
<th>Very high energy</th>
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<tbody>
<tr>
<td>aluminium</td>
<td>lime</td>
</tr>
<tr>
<td>200 - 250</td>
<td>3 - 5</td>
</tr>
<tr>
<td>glass</td>
<td>clay bricks &amp; tiles</td>
</tr>
<tr>
<td>50 - 100</td>
<td>1 - 4</td>
</tr>
<tr>
<td>copper</td>
<td>gypsum plaster</td>
</tr>
<tr>
<td>100+</td>
<td>0.8 - 15</td>
</tr>
<tr>
<td>wood</td>
<td>concrete blocks</td>
</tr>
<tr>
<td>100+</td>
<td>in situ</td>
</tr>
<tr>
<td>high energy</td>
<td>low energy</td>
</tr>
<tr>
<td>30 - 60</td>
<td>sand, aggregate</td>
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<tr>
<td>lead, zinc</td>
<td>fly ash, glass</td>
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<tr>
<td>25+</td>
<td>volcanic ash</td>
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<td>soil</td>
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<td>&lt;0.5</td>
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<tr>
<td>plasterboard</td>
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<td>8 - 10</td>
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### Structural design

**Sustainable material sourcing**

<table>
<thead>
<tr>
<th>Sustainable materials</th>
<th>Structural design</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tower of Babel</td>
<td>Baker McCarthy Consulting Engineers</td>
</tr>
</tbody>
</table>

### Place making

A central urban design axis occurs in the skyscraper design in two spatial continuities between street-level activities with those spaces at the upper-floor of the city's high-rise towers. This is due to the physical compartmentation of rooms. (Inherent in the skyscraper typology) Urban design involves 'place making'. By creating 'vertical places', our design bring the 'street life' to the building's upper-paths through wide landscape-ramps upwards from street level. Ramps create a continuous spatial flow from public to less public, as a 'vertical extension of the street' thereby eliminating the problematic stratification of floors inherent in all tall buildings typology. High-level bridge-linkages are added to connect to adjacent buildings for greater urban connectivity.
A prototype for a new generation of high buildings in the tropics, this Singapore tower explores Yeang’s principles of bioclimatic design more extensively than ever before. It adds many new ideas and contextual touches.

Yeast has long been associated with full eco-friendly projects, what he calls bioclimatic skyscrapers (see for instance AR February 1993 and AR September 1994). But up to now, though his buildings have shown steady evolution, they have been constrained by clients with understandably quite restricted programmes. The chance to try out ideas on a more speculative, yet possibly achievable level has come from a proposal by the Singapore Urban Redevelopment Authority who asked him to make proposals for an exhibition tower one that could contain exhibition spaces of all kinds, retail uses, and auditoria. This is projected to be what he calls “a prototype ecological building design” in which his green ideas can be pursued with more freedom than usual, and with greater vigour, over a wider range of issues of ecological concern.

At the junction of Waterloo and Victoria Streets, the site is not far from the fabled cluster of slender (and by no means elegant) towers that heraldically symbolize Singapore’s CBD. But when this 26-storey structure is built, it will be completely different from them: it will be covered with vegetation, eroded to allow for internal terraces and sky courts, brimmed with shades, helm-masked with shining solar panels and wrapped in ramps. The latter are intended to make ‘vertical places’, gently and easy transitions between levels of what Yeang calls the "inevitable physical compartmentation of floors inherent in the skyscraper typology". The most important ones run up the lowest six or seven floors to make what Yeang hopes will be a "vertical extension of the street".

Wide landscaped ramps conduct you upwards from road level, and are lined with street activities like stalls, cafes, shops, bars and so on; they lead onto the lower levels of the great exhibition building. The aim is to recreate the wonderful mix of uses, people and spaces which made streets of the richer cities of South-East Asia (Singapore, Hong Kong, and to some extent Kuala Lumpur) magically alive in the middle of this century. The buildings were modern concrete structures, but the wild mix of functions (department stores to housing, restaurants to workshops) was far more varied, lively and picturesque than anywhere else (sadly, modern development has replaced many of these wonderful but shabby tenements with uni-functional object buildings).

Yeast’s towers have always been intended to be shabby, intimately related to vegetation, which he uses not only as an amenity but as a means of providing shade and improving interior microclimatic and oxygenation. In the Singapore project, he proposes to go further. He regards the site as ecologically “devastated”, and has carried out a survey of local species to find which plants will be most suitable for the new building, and re-evoking the original eco-system. They are to make a continuous garment from street to crown of the building, winding through the ramps and vertical places. They will be nourished by rain which will be collected on the roof and in a series of "scallops" on lower floors. Rain will be augmented by grey waste water and the two will be filtered and kept in a tank on the roof to feed the irrigation system and lavatory cisterns.

The plants will be the only climate modifiers. Of course, there will be air conditioning, but its use will be minimized by built-in shading, fixed and movable, and by wind walls placed parallel to the prevailing wind to direct breezes to sky courts and internal spaces. Ceiling fans with de-misters will be used for cooling before the full air conditioning system comes into play. The photovoltaic arrays are intended to reduce demands on the national electricity grid to power refrigeration and lighting.

Solar thermal collectors will heat most of the domestic hot water.

One of the key concepts behind the building is loose fit, an idea that has been around for three or four decades, but which is rarely a conscious determinant of design. Yeang suggests that the tower could be converted wholly or in part to office or residential use, and has prepared a scheme for converting the entire building to offices at 75 per cent net to gross efficiency. Partitions and even floors will be removable, but solid enough to provide sound insulation where necessary.

Yeast also believes that the whole thing should be capable of being demolished with minimum waste of energy and materials. Hence, he proposes making all structural joints by mechanical rather than fusion methods (that is, in the case of the frame, bolting the steel rather than welding it). So the structure will be demountable and re-usable, and its elements like the floors, which he suggests will be made of innovative structural timber cassettes.

There are numerous other ingenious ideas in the concept, for instance methods of handling the building’s wastes (such as packaging and unused food), and composting solid sewage. It will be marvellous if the whole proposal can be realized, but even if only three quarters of the ideas are implemented, the shaggy tower should be an example for development in all tropical regions.
potential grey water gravity fed filtration system

the advantages are
- site specific
- 15% water saving
- low energy system
- based on established low technology
- recycled rainwater and greywater
- recycled water can be used for
  - flushing toilets
  - garden irrigation
  - indirect evaporative cooling
  - reduces mains water consumption of building

water recycling

30% water saving

potable water

recycling grey water

rainwater collection and recycling system

vertical landscaping

Vegetation from street level upwards as a continuous transition from a slope to the vertical facade

ground plane relationship

Vegetation from street level is uplifted up the building as a continuous ecosystem. This facilitates species migration and engenders a more stable urban ecosystem

views to the surrounding

Vegetation analysis was carried out to enable upper floor design to have views of surroundings

"Loose-fit"

Generally, buildings have life spans of 100-150 years and change uses over time. The design here is "Loose-fit" to facilitate future major features include
- Skydocks (as convertible for future office use)
- Removable partitions
- Removable floors
- Mechanical changing of materials to expand chemical bonding to facilitate future recovery
- Flexible design e.g. initially, a multi-use hotel building, as future use or office (additional area of 120,080 sq ft at 35% efficiency for apartments)

A series of plans to show conversion to office use has also been prepared for 75% net to gross floor efficiency

water-recycling

Water self-sufficiency (by rainwater-collections) in the tower is at 31%.

- Total net area = 3,567 sq m
- Building population = 1 person = 0 sq m
- Water consumption = 1.7 l/s per person
- Total requirements = 30 x 1.7 = 51 liters/s
- Total rainwater collection = 10,680 liters/day
- Total net area = 10,680 liters/day x 365 days = 3,939,600 liters/year
- Total non-rainwater collection area = 5.1 sq m
- Singapore average rainfall amount = 2,344 mm
- Total non-rainwater collection = 2,344 liters/year
- Water self-sufficiency = 31.2% = 3,939,600 liters/year
- Water self-sufficiency = 31.2% = 3,939,600 liters/year

water-purification

Rainwater-collections system comprises of roof-catchment area and layers of scallops located at the building's facade to catch rainwater running off 40 tables. Water "flows through" gravity-fed water-purification systems using sand and filters. The filtered water accumulates in a basement storage tank and is pumped to the upper-level storage tanks for reuse. For plant irrigation and water flushing. Main water is only here for potable needs.
solid waste recycling

separation of materials during construction to facilitate reuse and recycling
timber cassettes recycling

1. Remove timber cassettes from beam
2. Cassettes removed from beam
3. Cassette removed from beam
4. Cassette removed from beam
5. Cassette removed from beam

building materials recycling and reuse

The building is designed to have a basic structure and its structural connections to be integral to its reuse and longevity at the end of building's useful life.

sawdust recycling

The design utilizes a system and recycling of sawdust

- Estimated volume: 100 m³ per three-storey day
- Building population: 100 persons
- Sawdust produced: 100 kg per person
- Sawdust produced per day: 100 kg per person x 100 persons = 10,000 kg per day

Sawdust is collected in a compactor

- Sawdust is incinerated on-site

sawdust waste treatment

- Sawdust is treated in a compactor
- Sawdust is incinerated on-site
Solar Energy Use

- Photovoltaics are used for greater energy self-sufficiency.
- Average photovoltaic energy output = 0.15 kWh/m².
- Total energy output = 396 kWh.
- Estimated energy consumption: 10.097 kWh/m²
- Estimated daily energy consumption = 4.397 kWh.
- Self-sufficiency = 898 x 4.397 = 20.4%.

Solar Thermal Collectors

Solar thermal collectors convert solar energy into hot water and may be used to supplement the hot water provision in the building. They should be mounted at roof level as a stand-alone panel system.

Embodied Energy and CO₂

Embodied-energy studies of the building are useful to indicate the building's environmental impacts. Subsequently, estimates of CO₂ emissions arising from building materials production may be made. Design's embodied energy (prepared by our expert) is

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<th>Element</th>
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<td>7,793.00</td>
</tr>
<tr>
<td>External wall</td>
<td>5,950.30</td>
</tr>
<tr>
<td>External wall</td>
<td>2,864.50</td>
</tr>
<tr>
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<td>12,415.10</td>
</tr>
<tr>
<td>External wall</td>
<td>5,482.20</td>
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<tr>
<td>Other materials</td>
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</tr>
<tr>
<td>Roof and ceilings</td>
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<tr>
<td>Roof and ceilings</td>
<td>1,190.70</td>
</tr>
<tr>
<td>Roof and ceilings</td>
<td>1,736.60</td>
</tr>
<tr>
<td>Sanitary installations</td>
<td>490.20</td>
</tr>
<tr>
<td>Total</td>
<td>142,841.20</td>
</tr>
</tbody>
</table>

Energy sources affect CO₂ emissions associated with embodied energy. The majority of energy sources is petroleum-related (with some gas and electricity). 80 kg CO₂ per GJ of energy averages. The building here is associated with emissions of c. 11.5 thousand tonnes CO₂.

Embodied-energy values to gross floor area (GJ/m² GFA) are generally between 6 and 8, but may be more depending on methodology used. The design's ratio is at the high end (c. 14.2 GJ/m² GFA) but differs from others since using solar panels having high embodied energy will significantly offset operational energy saved over building life. High embodied energy materials used (e.g., aluminum and steel) are however easily recyclable and therefore halving their embodied energy when reused. Replacing concrete floors with composite timber floors can reduce embodied energy by c. 10,000 GJ.

By Professor Bill Lawson (Sydney)
- natural ventilation and 'mixed mode' ventilating
  The systems are the ASHRAE standard methods for any
  - single or building area
  - particular mode
  - background ventilation
  - high and low level mode
  The design have optimised the building's location
  - mechanical ventilation
  - heat recovery
  - exhaust systems

Local wind effects
by Edith McCarthy Consulting Engineers

Wind/wind manipulation

- Negative and positive pressures create lateral forces on the building's external walls.
- Adjacent buildings contribute lateral forces in opposite directions.
- Windows and other openings can be used to direct the wind.
- The design incorporates wind shadowing and shading devices.
cities in the sky
The Shanghai Armoury Tower, a project that follows from Hitechniaga, is distinct in two principal respects. First, it is deliberately designed as an iconic symbol — in Yeang’s words

"... the design is intended to create a modern urban (icon) form, for the clients’ progressive and valiant march into the 21st century".¹

Second, the programmatic content is mixed-use including hotel and office spaces. On an environmental level, as a design for a real building, the project extends beyond Yeang’s former work with the incorporation of a vertical internal atrium, and double-skin façade — both functions of a natural ventilation strategy.

Up to that date in 1997, the Shanghai project is the most potent combination of symbolic imagery and technical innovation, within Yeang’s overall portfolio of designs.

On a physical level, the design is intensively developed to produce a thoroughly responsive bioclimatic organism and an operationally energy-efficient building, that above all exploits the coastal climatic conditions of Shanghai and enables the occupants to be aware of both seasonal change and the outward prospect of the urban landscape through panoramic vistas.

As with Yeang’s other related projects such as Hitechniaga, landscaped skycourtyard gardens occur at vertical intervals providing internal-external buffer zones and acting as ‘green lungs’, which regenerate the microclimate of the building’s periphery. In addition to these, the major features of the inflected cylindrical form include the expressive vertical circulation systems, the introduction of zones of public space and the major formal element of external weather shields.

¹ Ken Yeang, ‘Shanghai Armoury Tower’ Project Notes
There are beautifully summarised in Yeang's characteristic and simple diagrams, which seen together, speak of his persistent development of vertical urbanism. Otherwise, what is of particular note in this project is the manner in which the shift in geographical location brings about a form that, particularly in cross-section, responds to seasonal climatic variation and change. Both the double skin facade and the important central atrium play significant roles in the modification and control of natural ventilation and air insulation. Also to the scenes of summer, mid-season and winter conditions. Equally, the incorporation of huge wind-breaker shields, which are adjustable to seasonable wind conditions, and the application of sun-shading devices, both bring solutions to functional needs and add layers of great expressive force to the architecture – literally and symbolically.

The rich innovations of these combined elements – especially the variable functions of the central atrium, sky courts and double skin facade, stand together as an important moment in the development of Yeang's architecture and the move towards a full ecological resolution of its basis.

In giving the Shanghai Armoury Tower its proper place in this evolution, the major attributes that are carried forward are those of a 'seasonal-responsive form' and the potential for that form to carry with it a cultural-symbolic message. While its overall technical terms, the analysis of the fabric, systems and operational modes, flexibility and future adaptability are increasingly acute, presented as integral to the project's conception.

**Shanghai, People's Republic of China**

*The Chinese Armory Tower is located in the Pudong District of Shanghai. The design is intended to create a modern urban icon for the client's progressive and dynamic march into the 21st century.*

- The 16-storey skyscraper is a symbolic interpretation of armaments found in military armaments. The sweeping panels of metallic screens on the exterior facade allude to the armament of the Chinese warrior. The curved solar panel atop the building emulates the shield, while the soaring tower piece is the 'ticket of the coat'. The stair plan suggests the trigger of a gun.

The detail of the Shanghai Armory Tower is a high-quality building. The external and internal design features use a bioclimatic approach to produce an operationally energy efficient building that makes most of China's coastal climatic conditions. Shanghai and allows for the occupants to experience and be aware of the changing seasons of the year.

- Landscaped sky terraces placed at strategic points in the lower represent buffer zones between the inside and outside. In addition, the air as oxygen generating 'green lungs', which touch the microclimate of the building. The external weather screen performs as a multifunctional filter against extreme climatic conditions while allowing generous panoramic views of the surrounding urban space.

- The blending of bioclimatic desires into architecture of the Shanghai Armory Tower will produce a building outstandingly unique in design and style and a proud and distinguished symbol of the owner.

*Engineering design objectives:* In order to achieve an efficient and low-energy performance building at high environmental quality, through the creative use of materials and skills, these building engineering objectives have been set:

1. **Maximize human comfort:** in terms of
   - good daylight and views
   - glare
   - appropriate thermal comfort
   - good air quality

2. **Minimize running costs and energy consumption** by
   - maximise the use of free energy, such as daylight, sun, wind, precipitation and temperature changes
   - high levels of thermal insulation
   - readily and appropriate control systems
   - efficient building systems and plant
   - use of low cost fuels at low peak ratios
   - maximum use of low energy and renewable materials

3. **Minimize capital costs:** by
   - reducing size of mechanical services
   - efficient design of services
   - reducing complexity of services
   - co-ordination of structure and services

4. **Minimize maintenance costs** by
   - utilising durable materials
   - long-life equipment
   - reliable and simple control systems
   - good access for maintenance

5. **Maximize usable space:** by
   - efficient planning
   - maximising plant area
   - removing the necessity for false ceilings
   - maximising structural/service integration

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energy saving strategies

strategy of moderating the internal temperature by passive means
and extending the 'mid-season' in latitude 31 14'N (Shanghai)

- Summer wind mainly from the south-east
- Mid-season wind through-out year
- Winter strong cold winter wind from the north-west

- Summer sun path (22 June) max. sun angle - 80°
- Mid-season sun path (21 March/23 Sept) max. sun angle - 63°
- Winter sun path (22 Dec) max. sun angle - 46°

- Sky-courts (open)
- Central atrium

- Double-skin facade: In summer it allows for natural ventilation by opening windows in the inner skin.
- In mid-season it is enhanced & controlled by adjustable louvres in between the skins.
- In winter the louvres can be closed so that the cavity becomes an insulating cushion.

- The central atrium extending over the whole height of the building & therefore the natural ventilation of the office spaces & hotel corridor feed to the atrium.

- Mid-season, natural ventilation to be enhanced & controlled by the thermal stack effects by thermal plume (atrium) & wind suction.

- In winter there is maximum mechanical air supply the louvres inside the double skin facade are open in order to cool the building with an early
6. Efficient planning in terms of:
   - good ventilation and views
   - manageability and security
   - ease of adaptability and flexibility
   - eternal circulation systems

7. Design for change
   - simple and modular design to cope with future change
   - ease of re-routing services to changing functions
   - inter-changeable modular design for partitions

8. Maximize creative space by
   - utilizing the interaction of structure and materials with the climate to provide a space conducive to working and increasing an awareness of occupants environment
   - maximizing the qualities inherent in construction materials
   - demonstrating the skills of local workshops

9. Protect and enhance ecological values by
   - integrating local fauna and wildlife
   - generating green and blue conditions
   - scientific landscaping
   - collection of rainwater and recycling
   - effective waste management and recycling

---

**energy-saving strategies**
Battle McCarthy (consulting engineer)

- Towers may be considered as vertical infrastructure from which humans may perform on plates in the sky.
- Shanghai Armoury Tower was conceived as an armature of structural grid and power and communication wire ways which are enclosed by elemental building envelopes sliced by floor plates.
- For the majority of the year the offices are naturally ventilated. Natural ventilation is enhanced by the air being drawn from the building floor plates by wind and solar-induced effects.
- During the winter and extreme summer periods the offices are mechanically ventilated with preheated or pre-cooled air respectively. The energy demand is supplemented by renewable energies such as sun, wind and ground water cooling.
- The structure consists of a rigid space frame supporting floors and perimeter cladding. The cladding consists of lightweight panels which moderate energy flow between outside and inside.
- The floors are serviced from a primary service core which runs for the full height of the building.

---

**energy management**

**global warming**
- Increased CO₂ emissions into the atmosphere will result in further global warming. At the Earth Summit in 1992 in Rio, and 1995 in Berlin world governments set out a directive to reduce CO₂ emissions. Yet the world energy consumption is expected to rise by 40% over the next 15 years to satisfy the needs of growing population and increased housing standards. 90% of the energy will be generated from fossil fuels (gas, oil and coal). This will result in an increase of 30% with possible catastrophic impact on our ecology as we know it.
- 50% of the world energy is consumed by servicing buildings. The Armoury Tower will demonstrate that high internal comfort conditions can be achieved economically without huge dependence upon fossil fuel consumption.

**running cost saving and reduced CO₂ emissions**
- The tower is a low-energy building which uses renewable energies to supplement the use of fossil fuel consumption.
- Typical office blocks of the scale would consume at least 600 kWh/m² per year prime energy which would contribute to at least 450 kg CO₂ per person per year. This is equivalent to a total of 20,000 tons CO₂ per year.
- The proposed tower design will consume less than a third of the energy of a traditional air-conditioned building. CO₂ emissions may be further reduced by the successful insulation of wind generation and solar collection, in the result, CO₂ emissions may be half of those from a conventional building.

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shanghai armory tower
The model of the year when the maximum load of solar and the load of convection, the building may be normally ventilated. To moderate the summer and winter climate extremes, solar gains are influenced by the sun angle and the sun's position is limited in the summer. The exposed half of the room side is protected a degree of external blinds and heat gain. The house under a period is to maintain the greatest the solar.

The building most use the solar gains and a small fan, be used as through the office. Where used in combination with might have ventilation, those help in location can be used between the other areas.

**Winter**

- **office - winter day**
  - Curtis window, north facing as is supplied by each floor.
  - Air is heated and at high level heat fans offer.
  - A heat source and window making use that within the air handling unit and will vary that only a minimum of additional heat air handling is required.
  - This air handling unit will operate on full load at, if necessary, to maintain a high level of air pressure and a temperature of 18° C.

- **winter**
  - The building is sealed and ventilation air is supplied to the offices to provide the maximum load as required in the air supply.
  - Heat recovery within the air handling unit makes use of the heat provided by the minimum inside equipment and outside solar gain.

**Heat sources**

- **office - mid season day**
  - During periods of mild weather (less than 30% of the year), the building offers combination of methods of mechanical ventilation and passive night time cooling of the climate to maintain acceptably conditions. The building system will be switched on and opened windows will permit easy ventilation.
  - The required cool air taken, which is pre-cooled in winter, will absorb the peak heat of the day and prevent the cool content is maintained.
  - During summer periods, ventilation will control solar penetration and load the offices.

- **office - mid season night**
  - By night, the air temperature falls and high level windows will operate to allow the air to cool the exposed interior walls. When the offices have been fully cooled the windows will close.

**mid season - March & September**

- All offices buildings via window at a low level
  - fans (option 1 and 2)

- Solar gains provide also driven ambient ventilation, by warming air between the offices and the space where this creates a negative pressure, with the office areas drawing to source from outside via 1 and 2.

**SUMMER**

- **office - summer day**
  - During periods of high external temperature (above 30° C) the building will have a tendency to overheat.
  - To maintain adequate conditions, the building of ventilation system will be adjusted to provide low, cooled mechanical ventilation in all offices. Air will be supplied from the air handling unit.
  - A cooled will result from a combination of air cooling and radiant cooling from the embankment of the exposed concrete walls, then requiring a smaller amount of ventilation.

- **office - summer night**
  - By night, the building's total load system will operate and then cooled through the offices. The data will fall accordingly be cooled, and the ventilation will be exhausted at high level.

**summer**

- During peak load conditions, the building is moderated by ventilation.
  - The air handling plant makes use of heat load and, with the cooler air will be exhausted at high level.

- **out**

- **in**

- **air handling**
office configurations

offices @ periphery

large rooms

small rooms

variation

large rooms

small rooms

offices @ centre

large rooms

variation

small rooms

open concept

single tenant arrangement
net leasable area = 82% typ. flr.

double tenant arrangement
net leasable area = 78% typ. flr.

multiple tenant arrangement
net leasable area = 74% typ. flr.

triple tenant arrangement
net leasable area = 75% typ. flr.
Within Ken Yeang's progressive development of projects for headquarters' facilities, offices and associated executive and training spaces, certain generic forms occur. The most obvious examples must include the enduring nature of Menara Mesiniaga, and transmuted - the design for the Shanghai Armoury Tower with its central atrium. Both of these are responsive cylindrical compositions which are capable of development into a series of related types, depending on the emphasis.

The Gamuda Headquarters is a subtle development of this lineage. Within the encirclement of a powerful ellipse, arises the creation of an enormous external public space - a garden atrium. While the built version is some 10 storeys in height, the same essential ideas and organisation could apply to a skyscraper of 100 storeys, or more.

That is to say that the essential principles of a peripheral ring of occupied space, a naturally ventilated centre, and a light central roof structure are all elements of an archetype - a summary of a generic type within Yeang's emergent architectural enquiry.

Taken as it stands, the composition of the Gamuda Headquarters is essentially simple, geometrically pure and biomimetic in its response. The main principles of orientation, shielding and the resultant plan composition are all inherited from the earlier models, but what is dramatically different here is the focused development of the inner atrium - on a grand scale - and the study of wind-flow pattern on both the elliptical atrium and the peripheral surround of accommodation, which includes landscaped skycourts, elevated garden terraces and roof gardens.

In designing the building to take advantage of prevailing winds, both the elliptical atrium and the elevated skycourts benefit from an environment where supportive air-flow sustains the occupants in a pleasant and beneficial manner. The heavy and appropriate emphasis on landscape as a major element of the project is further enhanced by the raising of the lower office floors some 12 metres above the ground plane. This sectional arrangement allows the central garden oasis of the elliptical atrium to flow into and unite with the water and tropical garden system which is prevalent throughout the business park setting.

The plan is an exemplar of major principles applied in a direct and simple part: the major sheltering service cores are situated at the hot east and west ends, whose external wall surface is minimised by the elliptical geometry. The long north and south faces are cut open by a slanting sliced bissection, which both opens the atrium, creating airflow and is crossed by breezeway bridges on both facades.
The wind tunnel test report by the consultant on the proposed Vizma Gamuda Park Headquarter was reviewed and studied. There are copious amounts of data contained in that report; however, some are more critical than others at the current stage of design.

The shape of the building, its proximity to other nearby buildings, and its orientation with respect to prevailing winds determines the local wind speeds affecting people's comfort and safety. Estimates of local wind speeds and their associated 15 minute occurrence for four speeds intervals were calculated from the maximum wind speed coefficients for each location measured in the wind tunnel study. In addition extreme conditions that might be expected based on 50 year return period gradient winds which approach 30m/s were calculated.

Design wind loads on cladding are from 141 measurement points on the wind tunnel model based on a gradient height design wind speed of 33 m/s are provided in Table 3c of the wind tunnel test report. The maximum value is 0.4444 kPa for location B9.

Estimates of natural ventilation are provided for minimum wind speeds needed to achieve 6 air changes per hour and the percentage of time winds from that direction equal or exceed that minimum wind speed. More extreme estimates of natural ventilation will be provided in the final report. It is clear from the estimates of natural ventilation due to wind and stack effect that:

- While stacks can occur for up to 45% of the time, occurrences are at night.
- Openings in external walls will need to be significantly larger than those currently indicated. Probable similar to associated doorway openings.
- During the 85% of time when there is wind, these winds could provide a 6 air changes per hour in stairwells and 4.5 for approximately 35% of time.
- In spaces with vertical continuity such as stairwells stack effect can provide significant ventilation.

Local wind speeds during normal wind conditions in the locations studied on the wind tunnel test model did not exceed Beaufort 4 (moderate breeze).

Figure 8 in the case of extreme 1 hour in 50 year storm events Beaufort numbers at 4 new locations reached 5 (strong gale) or below open velocities. This suggests that provisions should be made in the design to prevent pedestrians access to these locations. No. 33k, 33g, 33p, and 33l during such events.

Design wind loads on cladding at site from 141 measurement points on the wind tunnel model based on a gradient height design wind speed of 33 m/s are provided in the wind tunnel test report. The maximum design wind pressure in these data is 0.4444 kPa for location B9.

<table>
<thead>
<tr>
<th>Beaufort</th>
<th>Description</th>
<th>Mean wind speed</th>
<th>Range limits</th>
<th>Effects at high</th>
</tr>
</thead>
<tbody>
<tr>
<td>0/1</td>
<td>Light air</td>
<td>0.2 - 1</td>
<td>0.0</td>
<td>No noticeable wind</td>
</tr>
<tr>
<td>2</td>
<td>Light breeze</td>
<td>1.0 - 2.5</td>
<td>0.5</td>
<td>Wind feels on face</td>
</tr>
<tr>
<td>3</td>
<td>Gentle breeze</td>
<td>2.6 - 3.3</td>
<td>1.8</td>
<td>Wind extends upper arm</td>
</tr>
<tr>
<td>4</td>
<td>Moderate breeze</td>
<td>3.4 - 4.4</td>
<td>2.5</td>
<td>Upper arm and nose feel wind</td>
</tr>
<tr>
<td>5</td>
<td>Strong breeze</td>
<td>5.5 - 7.5</td>
<td>3.6</td>
<td>Winds strong enough to make umbrellas useless</td>
</tr>
<tr>
<td>6</td>
<td>Gusty breeze</td>
<td>7.5 - 11.5</td>
<td>5.5</td>
<td>Winds strong enough to blow small objects</td>
</tr>
<tr>
<td>7</td>
<td>High wind</td>
<td>11.5 - 17.2</td>
<td>8.5</td>
<td>Wind force can damage small objects</td>
</tr>
<tr>
<td>8</td>
<td>Very strong</td>
<td>17.2 - 24.4</td>
<td>12.5</td>
<td>Strong enough to cause damage to structural elements</td>
</tr>
<tr>
<td>9</td>
<td>Stormy wind</td>
<td>24.4 - 33</td>
<td>17.2</td>
<td>Winds capable of causing widespread damage to structures</td>
</tr>
<tr>
<td>10</td>
<td>Violent wind</td>
<td>33 - 51.0</td>
<td>24.4</td>
<td>Winds capable of causing widespread damage to structures and loss of life</td>
</tr>
</tbody>
</table>

### Location of pressure tapping points

- **Level 3 (points 65 – 98)** (between 7 to 9 floors)
- Maximum value (on gradient height) design wind speed of 33 m/s is 0.4444 kPa at location B9 (Level 3)

### Location of velocity measurements

**Plan View**

- Bridges (north)
- Bridges (south)
- Sky Camp & Bridges (west)
- Sky Camp & Bridges (east)

1 hour in 50 year storm, Beaufort 8 at R02, R03, E07 and E01
The whole of the enclosed accommodation is served by a continuous inner ring of single-loaded circulation, which encircles and views the elliptical atrium. Equally, the office space can view inwards across the circulation, or outwards from the periphery of the essentially ‘thin’ plan-form. This arrangement also maximises the provision of extensive natural-light and affords a first-class working environment for all occupants.

Detail studies of the sunscreen louvre banks and solar filters determine the appropriate level of solar protection and modify the daylight, while minimising heat gain and reducing energy costs.

The final major element is the over-sailing ‘free’ sculptural roof structure of the elliptical atrium, which is designed as a transparent umbrella rain-screen, allowing daylight to penetrate to the garden oasis beneath its sheltering presence. At the same time, the cantilevered outriggers of the roof-umbrella are intended to shield extensive roof-gardens.

What is clearly evidenced in this project is the well-rehearsed repertoire of Yeang’s passive low-energy building agenda; all the elements are present, from the naturally ventilated lift-core lobbies to the skycourt gardens and partially open circulation. To this basic framework he has added the ‘big idea’ of the sheltered atrium and the elliptical geometry. The whole is gathered together into a sustainable building in response to the United Nations’ agenda and towards a responsible 21st century architecture. For instance, in this case (as with all others that follow) Yeang has incorporated an Embodied Energy Study of the major building fabric – an aspect of his proposition that future design quality will be based upon knowledge – a substantiation of facts and of performance, quite as much as a spatial and aesthetic construct.

The Gamuda building, in its summary form is at once both simplistic and profound. Consistent rehearsal of principles and constant manipulation of form have enabled Yeang to reinvent the bioclimatic skyscraper in a number of notable types – the Gamuda-type, in itself, serves to inform a series of following developments, and in this sense, together with Menara Mesiniaga, is a benchmark project.
In order to assess the design for its embodied energy attributes, Davis Langdon & Everest Energy & Environmental Group were consulted. This group are internationally respected for their work on the embodied energy of construction materials and the consequential emissions of greenhouse and acid gases. They are particularly experienced in assessing designs over their full life cycle. They often contribute to the design process to help minimize the embodied energy and emissions without compromising the operational energy performance of a design.

The group use the technique of sensitivity analysis to look on critical dates and hence ensure that accurate and specific data is used for critical parameters whilst date of lower quality or less certain origins can be used for non-critical parameters. This allows accurate results to be obtained at minimum effort and cost. To facilitate their work, they have devised a range of tools.

A database of internationally published embodied energy factors containing over 5,000 items.

Detailed process analysis spreadsheets for the seven key materials that comprise about 70% of the embodied energy of buildings, eg. for:

- aggregates
- hence concrete
- cement
- brick and clay products
- wood
- steel
- plaster and plasterboard
- glass

An elemental estimator of embodied energy & CO2 for use at inception and the early design stage. The estimator provides both initial and life cycle results.

Estimating tool for assessing the transport components of embodied energy for the 4 largest mass and most transport sensitive materials:

- aggregates
- hence concrete
- cement
- brick and clay products
- wood

These materials contain over 99% of the mass of most buildings.

The approach used to assess the life cycle embodied energy mirrors that used for estimating the cost of the buildings. Estimates can be built up at different levels of detail appropriate for the different stages of design.

- embodied energy/CO2 benchmarks to help the client set a design target in the brief
- an initial estimate to assist the design team at inception and sketch design stages
- refinement of the estimate for the design as it evolves throughout the design process.

benchmarks of likely performance for Gamuda

Hence for Gamuda, which is a large prestigious air conditioned medium/ high rise building specified to high standards, he would expect the following performance:

Table 1 - typical benchmarks of performance

<table>
<thead>
<tr>
<th>attributes</th>
<th>units</th>
<th>range</th>
<th>low</th>
<th>high</th>
</tr>
</thead>
<tbody>
<tr>
<td>initial primary embodied energy</td>
<td>GJ/ m2</td>
<td></td>
<td>10</td>
<td>18</td>
</tr>
<tr>
<td>initial embodied CO2</td>
<td>kg CO2/m2</td>
<td></td>
<td>500</td>
<td>1000</td>
</tr>
<tr>
<td>life cycle primary embodied energy</td>
<td>GJ/ m2</td>
<td></td>
<td>8</td>
<td>14</td>
</tr>
<tr>
<td>life cycle embodied CO2</td>
<td>kg CO2/m2</td>
<td></td>
<td>600</td>
<td>1300</td>
</tr>
<tr>
<td>operational embodied energy</td>
<td>GJ/m2/m2/y</td>
<td></td>
<td>50</td>
<td>200</td>
</tr>
</tbody>
</table>

Hence minimising the operational energy should be the first priority before considering embodied energy/CO2.

Elemental results summary

Table 2 sums up the results from a more detailed design study. These results show that Gamuda will be toward the middle of the range of embodied energy/CO2 performance. The error on was only undertaken to the shell and core design stage and hence date of initial and sensitivity has not been elaborated further than an initial estimate. The principle way in which the design has been made more embodied energy/CO2 efficient is by ensuring that the vertical walls are not over specified and are structurally efficient. The extensive use of recycled materials is also beneficial due to their relatively low mass compared to alternative forms of construction.

Table 2 - elemental study of improved design

| Gamuda HQ summary results | measured (m2) | embodied energy (GJ prim) | embodied energy (GJ del) | embodied CO2 (GJ CO2) | life cycle embodied energy (GJ prim) | life cycle embodied energy (GJ del) | life cycle embodied CO2 (GJ CO2) | embodied  
|                           |              |                        |                        |                       |                                     |                                     |                                     | primary  
|                           |              |                        |                        |                       |                                     |                                     |                                     | % initial | % gross | % life cycle |
| Substructure              | 15927        | 155695                | 90778                 | 1679542              | 155405                | 96778                             | 1679542               | 155405   | 28%    | 31%        |
| external wall and façade | 20172        | 226282                | 126509                | 2346970              | 242201                | 139343                            | 2346970              | 242201   | 41%    | 43%        |
| steel frameworks etc.     | 6441         | 11452                 | 6449                  | 103377               | 23483                 | 13352                             | 103377               | 23483    | 2%     | 2%         |
| structural frame          | 20172        | 226282                | 126509                | 2346970              | 242201                | 139343                            | 2346970              | 242201   | 41%    | 43%        |
| external wall and façade | 20172        | 226282                | 126509                | 2346970              | 242201                | 139343                            | 2346970              | 242201   | 41%    | 43%        |
| steel frameworks etc.     | 6441         | 11452                 | 6449                  | 103377               | 23483                 | 13352                             | 103377               | 23483    | 2%     | 2%         |
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| steel frameworks etc.     | 6441         | 11452                 | 6449                  | 103377               | 23483                 | 13352                             | 103377               | 23483    | 2%     | 2%         |

Lessons learnt

Gamuda is an inherently high quality, high cost, high specification office development. As a result, its embodied energy/CO2 is likely to be higher than that for a more modest specification. It is also a fairly high-tech building which is engineered for structural efficiency. This allows it to be a moderate mass building which is beneficial for embodied energy/CO2. Modest physical mass (good for embodied energy/CO2) can be achieved without compromising thermal mass. This is because accessible thermal mass used for stabilising thermal temperature fluctuations requires only about 75 mm thickness of concrete which is small compared to the thickness required for structural purposes.

The dream

The ultimate low embodied energy/CO2 building might be constructed from a low (engineered) mass of mainly locally sourced natural and renewable materials (eg. wood). The design would moderate the local climate without the need for external energy sources to always provide comfort, health and productivity for the users of the building. The materials used would need a minimum of processing to make them suitable for construction and would not require toxic or noxious materials and by product wastes from production.

The constructed buildings would have a very long, flexible and adaptable life. At the end of their life, the materials would be reusable or recyclable locally with minimal processing energy. Alternatively, they may be useful as fuels for heating and electricity cogeneration without the release of toxic flue gases. At the very least, demolition material should be inert and non-toxic for simple disposal.

Clearly practical buildings must be a compromise between these aspirations and all of the other functional, aesthetic, and physical requirements of the building and our state of knowledge in being able to construct and operate them.
The Menara TA2 is seen as a related development for a residential and leisure assembly associated with the Menara TA1 office tower which stands on an adjacent linked site, within the Golden Triangle of Kuala Lumpur City, and in the immediate vicinity of the Petronas Towers.

Within Yeang’s range of tower forms, and in a basic generic sense, Menara TA2 and the MBF Tower in Penang share a fundamental typology that sets these projects apart. Both are residential developments with the main core of elevators and staircases within the centre of plan, leaving the encircling periphery free to accommodate the residences. Both towers share the principle of natural ventilation throughout the central space supporting the occupied areas.

The Menara TA2 remains a project, but its clear characteristics establish a definitive bioclimatic type form within an urban setting. The plan is composed of two interconnected, spatially separated, reversed L-form towers. The towers comprise a left wing with 6 metre ceiling height, and a standard wing with 3.1 metre ceiling height. The condominium units in both wings are a mixture of one and two bedroom units, and each one has unobstructed outward views across Kuala Lumpur City.

The space between the two towers rises as a vast central atrium, where the central elevator and stair cores rise around a cruciform of circulation that connects to encircling circulation bridges, giving level by level access to the sets of residential condominium units. The openness of this central volume and the vertical separation of the towers at the corners enables a free air-flow within the atrium inducing natural ventilation - this also assists the condominiums in that no unit requires mechanical ventilation. The placement of common facilities at vertically strategic locations throughout the building, further introduces openness and creates a sense of community. Coupled with the atrium, and generates a sense of vertical urbanism.
The vertical incidents of common facilities include a gymnasium, pool club and health spa with swimming pool, a main club house and various skycourt garden voids, together with a high-level business center. The roof level of the seven storey car parking podium is expressed as a multipurpose park—an exercise space and a venue for social events at the heart of the tower assembly. Each of these facilities together with the separation gaps between the towers, and the rising atrium develops interstitial air-flow, and equally these separation gaps and the translucent atrium roof provide natural light throughout the internal void.

The sense of amenity is enhanced by the exploitation of elevation and prospect—both the health spa, swimming pool and main club house lounge, restaurant and sky-terrace have potentially spectacular views over the surrounding city. Equally the diagonal corner units, and end units of both towers have especially strong locations and command of the outward vistas over the city and beyond to the landscape.

It is possible to imagine, that particularly during the calmer moments of the tropical evening, with balcony terraces open to the inner living spaces and with all the communal facilities in full-swing, the potential of the hedonistic lifestyle possible in a city such as Kuala Lumpur could be realised in this building.

In its sleek form and relaxed arrangement this proposition is much more than a ‘condo’—it is a residential inner city type of high quality that both offers the opportunity to celebrate the openness the climate suggests and collectively forms, a crucial element in framing the vision of the city, endowed with the release and stimulation of a vertical urbanism, as a new cultural form.

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**Kuala Lumpur, Malaysia**

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**Design Intentions and Features**

This mixed condominium/service apartment tower is designed to incorporate all aspects of high-end residential lifestyle. Located within the Golden Triangle and financial district, the tower was designed for a young corporate market included within the building features fibre optic connection to every room, the digital business centre, indoor/outdoor gym, railed multi-tandum sport park, members 'sky-club' courtyard tennis and squash courts. Units were split between single and mezzanine apartments with double-height living room and full-height solar protected glazing.

The form of the building was devised to allow maximum views across and surrounding single terrace while maintaining a naturally-ventilated central atrium space and core. The plan was split in two to allow cross as well as stack ventilation. As a result, every room, toilet and kitchen in each apartment are naturally ventilated inside the atrium a column free planted corridors linking each unit to the lift lobby.
level 27 - penthouse duplex 2- and 3-bedroom units

level 25 - observation platform

level 16-19 - 2-bedroom units @ 750 sq ft

level 16-19 - landscaped sky-courtyard

level 14-15 - 1-bedroom units @ 550 sq ft

level 7-26 - special 2-bedroom corner unit

level 3-6 - elevated car-parking

swimming pool and jacuzzi above car parking (option based on RM400 per sq ft selling price)

main entrance from Jalan Law Yew Swee
What the project demonstrates is that both the living and working environment can be united within the very heart of the city, rather than the separation of functions that creeping suburban developments impose, with all the attendant problems of traffic pollution and transportation.

The united towers of TA1 and TA2—the related condo towers—propose a new millennium appropriate to an emergent capital such as Kuala Lumpur, within the urban context of the 21st century.
The Maybank project defines a point in Yeang’s work overall, where the vertical scale of the skyscraper begins to be really significant.

In this case the vertical scale is enhanced by the insertion of tropical terraces, a version of the skycourt principle, which divides the building into four vertical office zones, with banking hall at the base and tropical roof garden at the summit.

Situated within the Singapore downtown of major tower-forms with a riverside plaza that terminates the Boat Quay waterside walk, the Maybank tower rises as a slender ‘blade’ of articulated floors, sheathed on the hot west face with a massive vertical plane of service cores, elevators and staircases. The east face is sheathed in a sophisticated double skin, which varies its physical condition according to time and user need. This facade is composed of three elements: an outer solar filter layer, an operable glazed facade, and supporting structure and spaces. This facade assembly allows users to control their internal environment both with regard to air-flow and natural light. The variable nature of the transparent inner skin acts as a glass filter, changing its translucency relative to time of day and the need for solar control and ventilation. Thus the facade engineering takes over a major expressive role, in the life of the building and its occupancy. During the day the inner floor plates suggest a series of inner spaces, delicately visible beneath the porous outer skin, while at night the radiant inner volumes expose the variety of inner space and its levels of occupancy. This counter sensation of opacity and porosity transforms the tower into an interactive shaft of light, which stands in sharp contrast to the other surrounding monolithic tower forms. Set in its context...
the Maybank Tower will be highly visible both from
within Singapore city and on the high-rise skyline.
As such it is truly a landmark project.

Elements of Yeang’s vertical urbanism are in
evidence. these include bistro and café
facilities, the extensive tropical terraces
with panoramic vistas and the use of ramps within selected vertical zones
as additional space integrators. The
whole assembly has the intensity of
movement and occupation that
ensures a visibly permeable, living
organism. In itself, the design is a
complete transformation of the
skyscraper, and clearly
exemplifies Yeang’s bioclimatic
architecture

The Maybank Tower is located within the major
commercial district of Singapore. To the north is the Singapore
River and the Boat Quay pedestrian walkway; to the south
is Fullerton Square and Raffles MRT Station. The building
is highly visible from within the city and will have a major
impact on Singapore’s skyline.

The features of the design are:
• The east and west facades are constructed in three
  elements: the outer solar filter layer, the operable
glazed facade, the supporting structure and spaces.

• During the day the facade and various floor plate engender
  a sense of spatial texture beneath the porous outer skin. The
  inner skin is a transparent glass layer changing its transparency
  according to the time of day and the individual need for
  solar control.

• At night the facade appears as a thin gossamer skin over
  a series of colonnaded spaces. The floor plates and their
  respective volumes radiate from behind the facade exposing
  the variety of spaces from within the building. The tower is no
  longer a impermeable vertical stacking of barreled concrete trays
  but allows social interaction, increased user activity and
  enhanced productivity.

• The service core to the west side acts as solar buffer to
  the hot west sun. The curved east facade is fully glazed
  allowing natural daylight onto the office floor plates and
  gives unobstructed views across the Singapore River and
  the Marina Bay.

• The building gradually changes its opacity and porosity not
  only during the day and the night but also according to ones
  approach and passage through the building.

• On Fullerton Square the tower opens on the long axis exposing
  physical access to the Boat Quay and visual glimpses through
  the towers voids to the sky beyond.

• A small north facing plaza connects the river front with
  the building base and the entrance lobby. This provides a
  transition to the Boat Quay waterfront walk and as the
  threshold between the river and the building. The plaza is a
  covered outdoor space servicing the Maybank’s Banking Hall
  and own offices with an upmarket lunch time bistro.

• The public plaza opens up and expands the physical and
  visual links between Marina Bay and the Boat Quay.

• The tower is designed to have seven vertical zones separated
  into open public and office spaces. The raised entrance plaza
  connects all three open public spaces – the banking zone is
  reached with a series of ramps, the mid-height interchange
  level and café is accessible from the express lift which continues
  to the Tropical Roof Garden. In between the Banking and
  Tropical Roof Garden are four zones of office space.

• Each zone is connected to the main lift core. Within each
  zone are additional space integrators linking the floors
  with ramps. These allow movement within a zone to be very
  efficient and conducive to multiple tenancy situations. The
  various zones are interlinked to their immediate neighbours
  via smaller shuttle lifts. Spaces between the vertical zones are
  additional to tropical terraces. Each terrace has a panoramic
  view across the water and skyline of Singapore.
The overall form and massing of the building's facades recall the BMW tower, while the braced structure of the north and south wings has a resemblance to Central Place. The use of the double-skin facade mimics the design of the Shanghai Armour Tower and the vertical suspension pipes and air void ventilation recall the technology.

It is reassuring to find the traditional architectural elements within the design. It is an exciting task to find the continuous research and application of various systems – in this case, the double-skin facade – which bring energy to each progressive design. The innovative methods of research development continue to be the central focus of maintaining the quality and innovative nature of the architectural production.
The project, essentially a high quality office tower, is both related in its form and response to two major sets of criteria, as well as to the general agenda of the Yeang green skyscraper typology. The first response is to the important urban location of Kuala Lumpur's most prestigious city centre development, including the Petronas Twin Towers. The building form addresses collectively KLCC, KLCC Park and the Mandarin Oriental Hotel, and offers extensive vistas. Much of the site area at ground level has been formed into a major garden and includes both a grand entrance plaza and a pedestrian plaza with cafe and entertainment area. The intention is to extend the adjacent park concept and to give priority to occupants and visitors to the building.

The second response is both functional/programmatic and to the same time formally symbolic, resulting in a vertical tripartite composition, of plinth column and capital. The plinth of four major floors includes a commercial banking hall and cafe facilities, grand entrance lobby and atrium, and together with a fifth level skycourt, function rooms, restaurant and club provides five levels interconnected by a rising grand ramp. The column of open plan office space then forms the major element of the vertical mass. This assembly is concluded by a capital of four floors, which provides the headquarters for the client, with a rooftop garden that cascades through three floors, together with two eastern pavilions with panoramic vistas.

The bank logo appropriately signals its presence, mounted outboard of this crowning cluster of accommodation, with executive penthouse and pool.

The formal and symbolic idea is framed in Yeang's description: "...the three tiered building allows the tailoring of technology and environmental aspects for each zone while projecting the Feng Shui philosophical image of a healthy man with his feet firmly on the ground, full well-fed body and wise head held high. Standing with its strong back to the sun, which carries the solar ribs up and over the roof top garden to create a shaded 'hat' ...".

What Yeang is referring to here is both the ecological form of the architecture and the implications of the distinctive imagery the building is intended to create as an innovative, inhabited landmark within the city.
Executive penthouse apartment with pool and garden oasis.

Solar shading.

Upper skycourt.

Service backbone and IT core.

Balconies allow for expansion and induce wind turbulence to aid ventilation.

Private garden balconies create natural shade and reduce the heat.

Views towards Jalan Pinang, Ascot Service Apartments and Entertainment Centre.

Private garden terraces provide oxygenation and sweeping views to KLCC Park.

Lower skycourt function rooms, restaurant and club facilities.

Vision wall addressing KLCC and Mandarin Oriental hotel.

Grand entrance plaza oriented according to recommendations from feng shui master.

Pedestrian plaza.

Vehicular entrance to lower grand entrance and VIP drop-off.

Pedestrian plaza and bank entrance.

Curved linear facade prevents poor feng shui address to surrounding buildings.

Garden site to encircle the town.
The skyscourts and terraces form a major expressive element in the vertical composition and its landscape.

"... the plinth, column and capital are... separated by organic areas ... in keeping with the garden tower principles a lower double and upper triple height skyscourt in combination with terraces at every level provide 'lungs' for the building and its surroundings. These reduce its impact on the city centre while providing public, semi-public and private spaces for the users." 7

The balconies also allow for expansion of floor-plate area and induce wind turbulence to aid ventilation. At the same time, garden balconies and terraces create natural shade and oxygenation, and assist heat reduction, while providing vistas to the city and adjacent park.

The shading of the whole building form has several important elements which influence both the plan-form and the external envelope. This includes maximising

"... the service core's thermal damping effect by placing the building's backbone to the mid-day sun, while wrapping the sun path with a flowing ribcage of louvres (applied to the tower). The aim has been to reduce solar gains, while scooping in light and natural ventilation passively before investigating active systems." 8

The project also includes two projecting vertical wing walls, which break the horizontal shades adjacent to each stair core, and cut back into terrace alcoves linked to the service core corridor and lift lobbies. The wing-walls maximise natural air flow induced by the tower's height and increased wind impact. These elemental devices of building configuration, vertical landscaping, shading and ventilation are all aspects of Yeang's sustainable, green architecture and are joined here by many other design features which are graphically catalogued, in vertical sections, as part of the project documentation that communicates clearly to the client, the benefits of Yeang's overall methodology.

Important amongst these features are the structure

"... formed by the service core and reinforced concrete columns [which] gives expansive clear span floors for instant flexibility and long term adaptability ... raised floors and deep ceiling plenums combined with generous risers are designed to avoid the problems of obsolescence with the rapid advancement in IT requirements." 8

In another sense, this design is carefully considered in its overall address of context. At the lower levels, the form incorporates a double sided vision wall which acknowledges both KLCC and the Mandarin Oriental Hotel, and in so doing axes as a major curvilinear determinant of the tower and its base. Balancing this element, the 'non-aggressive' curved facade of the tower is intended to prevent poor Feng Shui address to surrounding buildings. Similarly, the grand entrance plaza is orientated according to recommendations from a Fung Shui Master.
entrance and exit from Jalan Pinang for service and staff convenience

fire control room
covered VIP parking and lower grand lobby

primary vehicle entrance for VIPs and visitors facing Mandarin Hotel, including drop-off and parking

vehicle ramp to basement

service and M&E zone

executive lift & fire lobby toilets facilities

lower zone atrium zone escape stair

private balconies provide 1000 sq ft of future expansion

grand entrance stair

garden site park rising to skirt the building’s upper ground level

grand entrance plaza

escape stair solar shade

IT & service risers allowing for floor plate expansion & future development

M & E plant

grand entrance lobby and atrium

parking lot

VIPs and visitors facing Mandarin Hotel,

including drop off and parking

banking hall

pedestrian plaza to provide café and entertainment areas

M & E plant

column free floor span to maximised floor space

curtain wall cladding providing dynamic unbroken views of KL’s premier business & commercial district
Seen overall, what Young is increasingly disposed to deliver in his ever expanding range of projects centred on the comprehensive basis of the green skyscraper, is a balanced unity of technology, functionality and tradition. In the case of Waterfront House, his expectations of a vertical urbanism are most in evidence in the rising levels of spectacular sky courts and private gardens, while greater emphasis of public use is focused in the building’s plinth and its appropriate facades and spaces.

Within the teeming context of Kuala Lumpur city, the project registers as a fresh and radically different office-building typology and provides exactly the innovative corporate image requested by the client at the outset.
In one sense, the UMNO Tower belongs to the family of 'thin' plan types exemplified by Central Plaza and Menara TA1, both in Kuala Lumpur.

And, while all three demonstrate certain principles and witness Yeang's great skill in delivering a commercial product in a harsh market place, with added values beyond the client's expectation, the UMNO Tower stands apart. The reason for this lies in the realm of applied natural ventilation, its dynamic effect upon the building form, and the factor of aesthetic development this innovation has brought to Yeang's pursuit of an ecological architecture, situated within the skyscraper.

The composition of the UMNO Tower takes the familiar format of a base, with banking hall auditorium and car-parking levels, together with 14 floors of office space above.

The plan-form makes the best of a restricted narrow corner site with one massive shield-wall of elevators, services and of end-to-end staircases facing east/south east, defending the space from solar gain. The opposite west/north west facade is glazed and shielded with solar-orientated linear solar shades. For Yeang these design moves are natural and common place within his work. However, what makes the design exceptional is the formation of the two extreme ends of the plan.

In these key locations, relative to the wind-rose and prevailing winds, Yeang has introduced soaring vertical wall-lins that he describes as 'wind wing-walls' that direct wind to special balcony zones and act as pockets with 'air locks' for natural ventilation via opening, full-height sliding doors.
Essentially, these devices introduce natural ventilation by the creation of pressure at the inlet, induced by the wing walls, which effectively 'catch' the wind from a range of directions. The position of the wing-walls and air-locks within the plan-form are based on Yeang's own assessment, assisted by data from the wind patterns of the locality. The overall experimental nature of this system has been subsequently verified by CFD analysis with positive results.

The key reason for this experiment lies in the economics of the original project. Because of the low rental rates perceived to be applicable in Penang, the original project was designed for tenants to install their own air-conditioning units. Yeang therefore proposed the use of natural ventilation not simply as a source of fresh air supply, but as a true modifier of comfort conditions internally. Consequently, Yeang was able to claim that the UWO Tower is probably the first high-rise office building that uses wind as natural ventilation for creating comfort conditions inside the building. Other claims of 'natural ventilation' in high-rise towers use natural ventilation simply as a source of fresh air supply to the interior and not for internal comfort conditions.

The fact that central air-conditioning was subsequently installed, now means that the natural ventilation design provides a back-up system to the building, in the event of power failure. This factor, together with the natural ventilation and lighting of the service cores and stairs and the protective measures in ventilation of the building's mass, collectively results in a genuinely low-energy design proposition.

Aside from the simple and brilliant technical resolution of a plan-form generated by pure principles from studies of wind and sun path, all of which feed Yeang's following projects, he has also extended the expressive dimension of these forces in the overall architectural composition.
One of the ways in which natural ventilation can improve occupant comfort is to provide a passive low-energy cooling of the building, as through direct physiological effect on the occupants. For example, by opening the windows, we let the wind in and out in so we provide a higher indoor air speed, which heat the occupants inside feel room. This process is generally called comfort ventilation.

Introducing the outdoor air with a given speed into a building may prove a cooling effect even when the outdoor temperature is actually elevated. This is particularly true when the local wind is high and the higher wind speed entering the space increases the rate of skin evaporation from the skin of the occupants, thus minimizing the discomfort that they feel when their skin is wet.

Such comfort ventilation may be desirable from the physiological viewpoint, even when the outdoor temperature is higher than the indoor temperature, because the upper temperature limit of comfort is shifted upwards with a higher air speed. Therefore, even if the mean temperature is actually elevated by ventilation with the warmer outdoor air, the effect of the comfort of the occupants (up to a given temperature limit) might be beneficial.

The important factor is the air speed over the body of the occupants. This air speed can be further increased by the greater opening of the windows and also by the use of such devices as ceiling fans in closed buildings.

Contrary to popular belief that the incident impact of wind on the external wall gives rise to outdoor ventilation, it is in fact the oblique wind with angles of 30° to 60° away from the normal that can provide better ventilation conditions in rooms. When the wind is oblique to the building, a pressure gradient is created along the windward wall. This pressure gradient can be further increased by adding a single wing wall (a vertical projection one side of the wall).

The wing wall is simply a short wall placed perpendicular to an opening in the building (i.e., the orifice leading to the inside of the building). It is used in combination with the orifice as a device like a pocket to collect and direct the greatest range of prevailing winds (where there come from a range of incidences) into the windward side of the building. The device can be used to enhance the internal conditions of comfort (e.g., external air changes, temperature, humidity, etc.). The design of this device depends on local wind conditions, the plan depth and built form, and would need to be tested by wind-tunnel tests or by CFD (Computational Fluid Dynamics) simulations to ascertain effectiveness, size of openings, control components, wing wall size, and shape, wing wall orientation and location in relation to the built form, etc.

**Figure 1** shows the conditions without the wing wall. Wind A from a perpendicular angle of incidence hits the wall and the orifice. The flow that enters the orifice is A', which is generally smaller in dimension than the orifice's opening dimension A.

**Figure 2** shows the situation when wind comes from an oblique incidence to the wall and the orifice. The wind B hits the building's external wall, generating flow B' into the interior. Assuming that wind speeds A and B are the same, then flow B' is smaller than A', since wind B comes from an inclined angle of incidence.

**Figure 3** shows the situation with the addition of a perpendicular wing wall. The wall is located on that side of the orifice that should enable it to collect the greater range of prevailing winds. Which side of the orifice for the wing wall to be located depends upon an assessment by the designer of the wind data of that locality. In this instance, this is assumed to be primarily within 45° incidence from direction A' and B'. The flow through the orifice is C', which is equal to or greater than flow A' or B' due to the wing wall.

**Figure 4** shows a design with a wing wall at both sides of the orifice. This is better in situations where wind comes from an 90° spread of varying incidences (or varying times, directions, speeds, etc.) to the surface of the external wall of the building. The orifice should have operable panels (e.g., full-height latches) that operate as 'valves' to be adjusted depending on prevailing wind conditions for better moments and should be placed closer to the leeward wing wall for situations of greater included wind incidences.

The perpendicular wing-wall configuration is more effective at stagnating the approaching airflow which results in flow more perpendicular to the opening and with less contraction. In addition, the wing wall devices should also have moveable adjustable horizontal 'spokers' at each floor level to minimize vertical flow over the face of the building and so further control the incoming winds in the event of conditions of very high wind speeds.

**Figure 5** shows a single wing wall option which is more efficient for winds coming from inclined incidences than **Figure 4**.
The soaring, vertical articulation of the wind wing-wall as the major emblematic feature of the form, coupled with the dramatic, blank fuselage of the eastern facade introduces a sense of aerodynamic poise, heightened by the canted roof canopy and terminal wall-forms at the summit level. Equally, that Yeang has depicted the sectional form in relation to the height of $1 + \frac{1}{2}$ times the length of a mega-top jumbo-airliner is probably more than a subliminal reference to streamlining, air-flow and airframe form, which all find their place in this architecture – one which gathers the wind, in the pursuit of an overall ecological agenda.

What becomes clear, is that each of Yeang’s successive projects make a developing contribution to the next – extending the range with knowledge.
Introduction

"Your letter re: Conceptual Study for the proposed commercial development on the mentioned parcel of land..."

Site Information

- Site location: Lot 912
- Total site area: 21,290 sq ft (1,977.84 sq m)
- Site area: 21,290 sq ft
- Site area after road widening, building lines and drainage reserve setback: 14,197 sq ft (approximately)
- Site area after basement line or full basement area: 13,544 sq ft (approximately)
- Permissible building footprint: 14,357 sq ft (approx.)

NB: The above information was obtained from MAPP on 16 April 1993.

Gross built-up area:
- Plot ratio: 1.5
- Gross built-up area: 106,450 sq ft

These feasibility notes are based on the following assumptions:

- Assume setback line from all boundary lines
- Total land area: 21,290 sq ft
- Take proposed development to have a plot ratio of 1.5 (approved by MAPP)
- Therefore, gross floor area (GFA) excluding carpark: 106,450 sq ft
- Assume 75% efficiency, nett area: 79,837 sq ft
- Assume building carpark requirements: for every 400 sq ft area, one car bay to be provided

Proposed Building Area

- Proposed GFA (excluding carpark): 106,450 sq ft
- Assume typical floor: 8,200 sq ft: 106,500 sq ft + 8,200 sq ft
- No of floors: 13 storeys
- Assume building footprint per block: 78 x 110 = 8,580 sq ft
- Total gross area (excluding carpark): 106,450 sq ft
- Assume 75% nett efficiency, nett nett area: 79,837 sq ft

Carpark Calculations

- Assume for every 400 sq ft nett: 1 car bay to be provided
- Therefore, no of car bays required: 79,837 / 400 = 199.58 bays
- Assume 30% reduction for Bumiputra status: 40 bays
- Total no of bays to be provided: 140 bays
- Assume 1 car bay: 350 sq ft
- Total carpark area: 140 x 350 = 49,000 sq ft

Proposed Built Form

- The proposed built form shall consist of:
  - 4 floors of basement parking: 49,000 sq ft (140 bays)
  - 13 floors of office block
  - Gross floor plate area: 8,200 sq ft
  - Net floor plate area: 6,150 sq ft
Four test boreholes were conducted, to a depth of about 45 m for the sub-structure design. Generally, these indicate the site to be undrilled by successive layers of very stiff to soft clay, followed by medium stiff to very stiff silt and sandy sand. Ground water table is between 2.7 m to 3.5 m below ground level.

Column loadings vary from 3,200 tonnes to 1,800 tonnes for the widely-spaced columns. For the more closely spaced columns, the loading is about 740 tonnes.

In the selection of foundation for the structure, shallow foundation like pad footing and raft was considered to be obviously not suitable in view of poor soil (N-value of 3) to a depth of 9 m below ground level. Bored piles was not adopted in consideration of high water table with silty sand and low N-values at the upper layers. The requirements of long length of steel caissons associated with boring in such soil to prevent collapse of bore holes would not merit value engineering decision.

For such soil condition and medium range column loadings, it was considered appropriate to adopt driven reinforced concrete piles. Further reasons to justify the use of driven r.c. piles are that they are economical (compared to steel piles) and could be installed relatively quickly. Piles used are as follows:

- **size:** 400 mm x 400 mm, with welded joint
- **grade of concrete:** G15
- **driven length:** average 55 m
- **working load:** 185 tonnes
- **maximum no of piles/column:** 8

Essentially, these are skin friction piles which mobilise the good soil resistance properties at depth of 30 to 55 m.

The idealised structure consists of moment resisting frames coupled to a shear wall. Horizontal and vertical r.c. members are rigidly connected together in a planar grid form which resides lateral wind loads primarily through the flexural stiffness of the members. This type of structural system is efficient to enhance the sway serviceability performance of the building. The structural analysis was carried out using the computer software STAAD-FT, with the appropriate gravity loads and wind loads, derived from a basic wind speed of 35.8m/s (80mph).

The maximum computed horizontal deflection of 98mm, is well within the deflection limit of H/500 (85m/500 = 170mm).

The building was designed for conventional r.c. beam and slab construction which is economical for such medium height range. The quantity of concrete (G30) and steel reinforcement (fy = 460 Mpa) used for the superstructure are as follows: **Concrete:** 5,896 m³; **Steel:** 1,195 tonnes.

To achieve an early handover of the lift r.c. wall for lift installation, the contractor adopted the 'Jump Form' method of construction with a construction cycle time of 8 days for 3.9 m height of wall. With this method, the contractor completed the r.c. wall construction 3 months ahead of the other areas which was constructed using normal steel and timber framework. The entire project, including piling works, was completed in 22 months.
Ventilation and comfort

Ventilation is needed for occupants breathing and to exhaust odours. It can also be used to exhaust heat gains although generally this requires some form of cooling. The example for a typical density of office occupation, 1.5 with of fresh air ventilation may be needed to supply the ventilation needs together with the rate of 0.5 air change may be required to exhaust typical office heat gains. Such that the internal air temperature is within about 2°C of external air temperature. For air movement associated with ventilation can provide comfort cooling for people especially in the hot humid conditions of Malaysia, where air movement across the skin can increase evaporative heat loss, instead, traditional Malaysian building design promotes high levels of natural ventilation and air movement by using large openings in the external facade in order to increase wind-driven cross ventilation. This, together with solar shading provides an environmentally sensitive design that can provide comfort conditions for much of the time. However, modern buildings in many polluted cities locations tend to be designed such that they totally reject the climate and rely on air-conditioning and artificial lighting. Air conditioning comes with high energy and operating costs and there is a growing concern over the quality of indoor environments in air-conditioned buildings, and the health of the occupants. In relation to some plants of 'buildings syndrome' and poor indoor air quality. There is an increasing interest in buildings that combine the benefits of natural and mechanical ventilation in some hybrid form, with mechanical ventilation only operating in spaces or times when it is needed. The diagram provides the potential for using this hybrid approach to environmental design.

UNMG form, orientation and location of openings

The form of the building with its wing walls and balconies has been designed to direct the wind pressure to the main ventilation openings. Each floor of office space is open plan with most work plants having access to an operable window frame and natural light. The main openings are in the form of windows and balcony doors, and are located on the south west and south east elevations. These allow for cross ventilation driven by the prevailing wind conditions. Some windows are located along the north west facade for user controlled ventilation. Figure 3 shows a typical office floor plan with the main openings identified.

VSD analysis

The wind speed will increase in height according to a power law relation as shown in Figure 1. In order to assess the potential for natural ventilation the wind pressure over the building's external surfaces needed to be estimated at the opening location. This was normally carried out using a physical scale model in a wind tunnel. However, this was not an option in this design and therefore a mathematical wind tunnel analysis was carried out using the CFD software Fluent for the wind tunnel model.

A model of the building was generated mathematically in the computer and used to obtain an estimate of the surface pressure at each opening. The wind map for the site shown in Figure 1 indicates that a typical wind trajectory for the site would be an angle of 45° and 45° from ground level, and a south west generating wind direction to the power station. Figure 1 was then used in the surface model to assist the assessment of air movement around the building for wind pressure contours. The maximum wind pressure contours were shown in Figures 4 and 5. Figure 4a shows the wind pressure contours around the building for wind.
The effects of direct/global solar radiation is significantly intense in the summer season terms of controlling this effect.

The problem is however, concentrated on the curvature of the facade where it faces west, and hence this 'component' is where the shading system has to be most effective.

Climate data on solar radiation also shows that it is about 4.00pm to 5.00pm direct/diffuse radiation (and also temperature) start to significantly drop (vertical), angles for this time shows about 18-20 deg).

What is recommended is a shading system with two main components:
1. One whose dimensions/cross section can be derived from the present one
2. A 'separate' component dealing with the high intensity incident of the curvature.

To deal with the intensity of direct radiation (2) should either be:
1. A vertical shading system that cantilever about 2 or 1.75 x the length of the existing frame of present shading system possibly made with perforated metal to admit usable amounts of daylight.

or
2. A 'tilted' system, with the present 'cantilever' with an approx 15-20 deg tilt for vertical can be made by present construction materials/components. This might serve better in satisfying the requirement of provision of view for occupants.

An additional feature which has resulted in improved daylighting efficacy is the inclusion of a lightshelf system into the design.

Research in temperature summer season has shown that besides reflecting heat in space, the lightshelf provides more uniformity for illuminance values at the workstation as compared with other vertical/horizontal/tilted shading system.

To control the effects of heat gain, it is recommended that the upper glazed portion above light shelf be made of glazing material that is lower in shading coefficient values. This will be ideal as also the use of glazing, in this portion of the glazed wall with high solar shading coefficient and high transmittance such as tinted or reflective low-E glass.
**Sketches for improvements to west facade sunshading**

- Sketches of sunshades:
  - Cascading sunshades
  - Integrated components
  - Separate sunshades

**Elevation**

- 1st floor plan
- 2nd floor plan
- 3rd floor plan

**Sections**

- Interior sections
  - 1st floor
  - 2nd floor
  - 3rd floor
Dubai, United Arab Emirates

owner: Dubai Municipality, United Arab Emirates
location: Dubai, United Arab Emirates
latitude: 25.11°N
nos of storeys: up to 18 storeys (over 27 blocks)
start date: 1998 (design)
completion date: 
areas: total built-up area 863,550 sq m gross
site area: 124,688 sq m
plot ratio: 1:5

Design features:
- The project is located in a prominent waterfront site between two limestone sections in central Dubai Creek Town: City Center, Dubai International Golf Club, Alkhor Park and AlMakhtoum Bridge.
- The site enjoys panoramic views across the river to Alkhor and Alkhair Park to the south and Alkhor Park and the Golf Club to the south.
- The site has an area of over 1.3 million sq ft with a promontory Floor Area Ratio (FAR) of 1.5, which gives the development great flexibility in design and use and high potential economic returns. However, there is a building height restriction of 11 storeys or 55 m which places a constraint on the site's building massing.

The site is located on a heavy traffic zone area at the crossing of AlMakhtoum interchange expansion with Alkhor main road. Due to this proximity to intersection, the site has limited vehicular access points off the main road. The road frontage is also limited as the southern boundary is taken up by the waterfront.

The brief calls for a mixed-use complex with housing, offices, tourist and commercial units, as well as landscape areas.

Masterplanning:
- The project's masterplan overall objective is to address the site's context and the men.
- Design: Water is brought into this site to enable access by boat and to contribute to lowering the ambient temperature at the development (see below).

Site massing:
- The massing proposal involves a scheme to address the existing site density and height reduction as follows:
  - All car parking spaces are located in the basement in order to free up the ground level for landscaping and recreational use.
  - By placing the cars in the basement, the building height can also be reduced.
  - Water is brought into the site in various internal views and to create the waterfront recreational space (e.g., marina, waterfront promenade, etc.).
  - The buildings fronting the waterfront are situated at ground level.
  - Setting up an area for recreational use.
  - Increase in building height to 70 m. In formal discussions held with the Department of Civil Aviation, it was suggested that there may be a relationship between building heights restrictions from 55 m to 70 m.

Hotel:
- The hotel is located at the most visible position from the main road at the southern corner of the site.
- The hotel is served by a high-rise vehicle drop-off with a prearranged car-parking located underground.
- The hotel suits has views both to the waterfront to the west and the city centre to the north. Its 'house shape' offers views towards the surrounding pool deck while directing the views towards the park beyond.
- The hotel serves the business demands generated by the proposed office buildings as well as launches into this location.
- The site has great potential such as the City Centre shopping mall, Dubai Creek Golf Club and AlKhor Park would be further enhanced by the proposed new waterfront development and shopping mall.

Serviced apartments:
- The serviced apartments are connected to the hotel for central servicing and shared use of club facilities. The apartments have direct views towards the waterfront and new marina.
- The hotel and serviced apartments are located on the northwestern corner of the site-upgraded by the new marina.

Apartments:
- The apartments are located at the waterfront edge and command the best views in the development.
- The apartments have been given a close relationship to the office towers and retail shopping mall.
- Each apartment block has a separate car drop-off to the main lobby and are directly accessible from the basement car-parking underground.
The Dubai Towers project is essentially very different from Yeang's definitive skyscraper typology, in both its form and location.

Set in a distinctive waterfront position, in central Dubai, the site and buildings enjoy panoramic vistas across the river to parkland. The permissible building height is restricted to 70 metres maximum, and road access is limited to the linear highway frontage of Baniyas Road.

Yeang's overall design strategy is essentially that of a huge partially buried plinth which houses car-parking and retail shopping mall with a landscaped roof which descends gently to a new waterfront promenade and marina, and which brings water into the site-enhancing views and recreational space. Over this massive landscaped base Yeang has located a series of cantilevered linear-towers, whose ends are lifted above the lower landscape, and are set at approximate right-angles to the waterfront. The towers are separated but linked, for ease of circulation. The overall result of this arrangement is a 'sliced' form which is entirely driven by considerations of wind and natural ventilation and the maximising of the vistas and prospect.

Yeang's summary of the bioclimatic response contained in the formal arrangement makes two significant points: first, that channelled air movement between the linear towers increases air movement and cooling effect, and next that complementary shading between the linear towers lowers radiant air temperature. Coupled with these overall principles Yeang has utilised a traditional concept of the wind tower, to ventilate basement car-park levels through to the podium roof. Thus, in overall terms the whole intensive layered form can be seen as a direct conceptual model, which is harnessing wind and hence ventilation, and providing shade over new landscape of planting and water. Yeang's policy is developed in more detail: '... the proximity of the creek - river water mass with the city water mass behind the development can give reversal of wind directions during the daily cycle. During the afternoon when the land mass is warmer the cooler sea breeze moves in from the water towards the land. In the early morning when the land and building masses have been cooled with night radiation to the sky, the dense cool air moves towards the water mass.'

The design is inextricably evolved from this statement, and then enhanced in detail throughout the programme of mixed-uses.

Of all the bioclimatic elements, beyond the wind and ventilation strategy, the landscaping is the most significant, re-introducing organic mass and lowering ambient micro-climate temperatures. The project includes both ground and vertical landscaping, and including water coverage represents 90% of the entire site area. This is largely due to the massive landscaped ground plane extending from the promenade upwards, over the whole podium. Landscaped sky courts are also incorporated into the higher levels of the buildings.
The hotel is located at the rear smaller position from the main road at the northern corner of the site. The hotel is served by a high-class vehicle drop-off pit arrangement car-parking located underneath.

The hotel uses its views both to the waterfronts to the east and the city centre to the north. Its high-level presence this time the swimming pool area while the non-room views to the north.

The hotel serves the business demands generated by the proposed office buildings as well as tourists to this location. The various.aspect conditions such as the City Centre shopping mall, Durban Country Club and Convention Park are further enhanced by the proposed new waterfront development and shopping mall.

**Service Apartments**

The service apartments are connected to the hotel for central servicing and theming of all facilities. The apartments have direct views towards the waterfront and new waterfront.

The hotel and service apartments are located on the northern segment of the site and separated by the new riverside so differentiable from the rest of the development. This allows for better security of its premises.

**Apartments**

The apartments are located at the waterfront edge and command the same views as the development. The apartments benefit from a close relationship to the office towers and retail shopping mall.

Each apartment block has a separate car drop-off to the main lobby and are directly accessible from the apartments car-parking underneath.

**Offices**

The offices are located on the east side of the development to take advantage of the road frontage. It is essential that these offices are very visible from the surrounding areas.

The office spaces are above the retail podium. Each office block has a separate car drop-off on the lower ground (pampered level) and are directly accessible from the apartments car-parking arrangement.

**Retail**

The retail shopping centre directly faces Emmanuel Road and has its main entrances on the street end.

The roof of the shopping centre is landscaped with shopping pavilions. They command panoramic views over the marina and creek.

**Car-parking**

The car-parking for this development is located on the lower ground and basement levels due to space limitations and height restrictions. Very little ground over parking is permitted and where this is prohibited it with shopping visits, women and families in mind.

The top level of the car-parking, lower ground level, is the drop-off point for the offices. This allows a secure, vandal-proof and secure nature!! (it is also wall-located it is served by a small and elegant "boardwalk" that runs all views of the water.

**Mosque**

The mosque is located on the island side directly at the waterfront. The mosque area will be accessible to the public.
As well as the natural sun-shading created by the separated linear towers, sun-shade structures in the form of louvered screen attachments are extensively applied to the linear facades. On the level of programme and urban design the project is intensively mixed-use, with extensive Shopping Mall including departmental store, supermarket, food court and specialty shops distributed over the basement parking levels. The linear-towers incorporate both Apartments and Offices, together with a stretched ‘horse-shoe’ form Hotel.

The Hotel is a major 400 bedroom and suite configuration surrounding a courtyard with swimming pool and outdoor cafes. The wings of rooms all command a variety of outward views, and the corridors include skycourts for natural light. The accommodation includes roof top garden terraces which also have spectacular vistas over both waterfront and park. As with Yeang’s skyscrapers, such as the Singapore EDBTT Tower, the consideration of outward prospect and view is always a major priority.

The eleven Apartment buildings, in linear-towers are ‘thin’ forms which encourages cross ventilation through the apartments. The terminal ends of these buildings are cantilevered over the water and include facilities such as gymnasium, coffee-houses and function rooms, together with special penthouses on upper levels. Again outward views are a concern, throughout. The offices have a similar linear-tower form, located above the retail podium. The elongated plan with minimal columns allows both flexibility of sub-division and provides maximum natural lighting to the interiors.

Many other aspects of the project such as structure, access and circulation have been carefully innovated and integrated into the overall concept and layout. The project also includes a Mosque, which is sited on a waterfront ‘island’, in a tranquil location facing west, towards Mecca.

But, what remains as singularly important to this project is not its formal arrangement alone, rather it is the manner in which the bioclimatic response has driven that arrangement into a natural climate-controlled result.
wind and natural ventilation

The proximity to the Creek water mass with the 'city' water mass behind the development can give several of wind directions during the daily cycle. During the afternoon when the land mass is warmer the cooler sea breezes move in from the water towards the land. In the early morning when the land and building masses have been cooled with night radiations to the sky the dense cool air moves towards the water mass. The orientation of the building blocks at right angles to the water assists in encouraging free movement of air between the building blocks assisting the natural cooling of the buildings.

The proximity of the building's facades assists in channeling air through the site while vertical gaps act as thermal barriers moving air vertically and in doing so cool the building fabric.

In traditional buildings, this movement of air has been utilized in the use of 'towers of wind' to ventilate occupied accommodation. This principle is used in the development to ventilate the carpark levels. Large light and ventilation wells from the podium roof into the basements function as wind towers, drawing fresh air into the basements and extracting used air.

landscaping

Ecologically and bioclimatically, we should use landscaping and planting to lower ambient microclimate temperatures as well as to re-introduce organic mass back into the essentially urban and mostly inorganic location.

Ground and vertical landscaping is used extensively around the development. The proposed scheme boasts 90% landscaping (including water mass) of the entire site area. This is achieved by extending the landscaping from the waterfront promenade level up to the retail podium roof in one continuous plane, below the elevated building blocks. Landscaped skylights are introduced in the upper floors of the buildings.

The earth excavated from the new marine bays are used to create landscaped mounds between the elevated buildings and the basement car-parking roof, reducing costly export of earth from the site. The earth acts as thermal insulation for rooftops.

sun-shading

Shading of both primary and external spaces is an essential and important part of the design. The need is there to protect the treated internal environment from direct solar radiation and in doing so reduce the energy demand of the building's environmental systems and at the same time improve the overall comfort of the spaces.

The sun-shade structures will emanate as external louvred screen attachments to the facade of the buildings. The space between the external screen are cooled by wind movement through it's porous form.
The internal circulation within the shopping mall is organized in a loop configuration along the edge of the site. A three-level departmental store, supermarket, and food court is located at one end of the loop while some specialty shops line the circulation loop.

The roof of the mall is an open landscaped plaza with retail pavilions, restaurants, and cafes with outdoor seating overlooking the marina.

Office Scheme: The offices are located above the retail podium. The offices have their entrance and car drop-off on the lower ground floor of the podium. The lift cores are located on either end of the office building giving unimpeded office space for all tenants.

The rectangular floor plan with minimal columns allows maximum flexibility for the interior partitioning of the floors. The elongated plan provides for maximum natural lighting into the interior space.

High-level links between office buildings enable one to access the next block without having to return to the ground floor lobby. This also facilitates articulated office spaces between blocks for office expansion.
The Makkah project is amongst the largest proposals that Yeang has made, and where the emphasis shifts to urban design and the relationship of the whole assembly of buildings to the existing city and topography.

The linear site is framed within a major network of roads and urban highways on the periphery, with a main access road (and service road for deliveries beneath) forming a linear traffic circulation spine, with the buildings distributed alongside, on the crest of a hill above. The whole assembly is within walking and viewing distance of the al-Haram, the focus of world pilgrimage to Mecca.

Yeang's central response is to create a "... unique, calming green park environment for the pilgrims ... careful planning and resource management can turn the Jabal Omar site into a green area, shading the external spaces and creating a pleasant environment in which to carry out pilgrimage ... a shaded place from which to view al-Haram."

The whole design then springs from the conceptual basis – a series of V-form towers on and over a spinal concourse with car-parking and retail development sunk below a massive landscaped roof. The irrigation water supply is sourced from the recycled 'grey water' of the whole development and planting and vegetation are selected on an indigenous basis, that require minimal amounts of water, and that can withstand the harsh climate. The major levels of horizontal planting are joined with groves of palms on the lower rock slopes, uniting to create a 'sea of green' between the Jabal Omar site and the al-Haram.
... the towers are raised above a concourse which collects the circulation and channels the population down two chutes to the praying plaza. The towers are configured to fulfill in particular the provision of a clear view to al-Haram from each apartment or hotel room, and from the concourse edge. The shapes of the towers are reminiscent of an opened Koran as a constant reminder of the pilgrimage."

The design concept is expanded in a series of studies which include Young's Ecological Approach, Built Form and Sight Lines, the collector Promenade and Chutes, Travel Time analysis, Prayer Zones and Prayer Areas. The overall concept is further studied in section, relating the height of the towers to a 450 m general height limit of the surrounding rim of mountains, with two signature towers rising above this level. Young envisages the idea of a Future Rim of mountains and towers as a model which could be extended from the Jabal Omar site into the surrounding hills, so that in this sense the project design is related to a regional vision, beyond the central city.

The towers and their detailed design emphasize Young's ecological design principles, considerations of room alignment and visual, pedestrian travel and the location of prayer areas, in particular. The towers are generally oriented east-west with solid perimeter walls and circulation on the western and southern faces, depending upon configuration and type. A major feature of this high-rise is a roof level wind-scoop which draws air into an evaporative cooling tower, in the center of the hotel plan, for example. Young's descriptive notes and sections define this principal element.

... a cooling tower through the central of the high rise is integral to the design of the development ... this tower brings warm air into the top of the tower where a fine mist spray cools and humidifies the air. This cooled, moist air drops down the towers, cooling the corridors and providing a fresh air supply to all rooms and apartments. The cool air exits the tower at the level of the roof garden, cooling the garden and prayer areas."

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**Jabal Omar Towers**

Owner: Makkah Construction and Development Company

Location: Mecca, Saudi Arabia

Latitude: 21° 27' N

No of stores: 1 apartment towers at 35 stories
2 hotel towers at 50 stories
4 hotel towers at 25 stories

Date Start: 2000 (design)
Areas: Gross area 878,880 sq m
1. Total net area 566,650 sq m
2. Prayer terraces and landscaped gardens 94,000 sq m
3. Car parks 309,000 sq m

Site area: 232,000 sq m

Plot ratio: 1.38

Design features: generic urban design strategy

The Haram is surrounded by live mountains that form an existing "rim" to the Al-Haram area. Our urban design strategy is to build the inevitable high-rise hotel by a height limit of 2000 m which will create a new "platform" rim around the Haram. This will avoid a rampant discolored skyline around the holy area. A new benchmark building height is thus driven from the average height of the live mountains at 450 m as the new height limit for future development of the site surrounding al-Haram. Only one or two exceptional towers at pre-selected locations may exceed this height limit to give some diversity to the skyline reminding the natives of the traditional mosque.

Masterplan: the proposed development at Jabal Omar uses the mountain crest to define the site into two parts, one facing al-Haram and the other sloping away from al-Haram. The parts of the development facing al-Haram contain the concourse and pedestrian links to al-Haram itself. Hotel and apartment towers are situated on the mountain crest, limited by our new "line" height for maximum views. The western side of the development is for car parking and vehicular access.

Accessibility to al-Haram: a central promenade (the concourse) at level 2 acts as a 'collector' to collect pilgrims from all the towers, who are directed to the two "chutes" to al-Haram. A contribution of elevators, escalators and pedestrian routes is used for reducing the travel time. Travel time analysis has been studied to verify the time needed to reach the Haram from the rooms of each tower.

Views of al-Haram: Tower block forms with single-loaded rooms or apartments are shaped for maximum arcade area with views towards al-Haram, using a number of tower typologies (e.g. A, B, M and composite shapes)

Green park: a green park environment is created for pilgrims, by landscaping of the car parks, roads and the concourse area. These are connected via landscaped bridges. The water supply for greening of the development comes from the recycled grey water of the development. The concept seeks to create a balanced ecosystem on the site of both organic and inorganic aspects of the ecological environment. Its simple level of sustainable design, the landscaping over the roads literally provides a green scheme by covering the car parks with earth and greenery. The car parks can be excluded from the plot ratio calculation, thereby increasing the developer's permitted commercial area.

Evaporative cooling towers: As a passive low-energy air conditioning design, evaporative cooling towers are located within the towers to provide cool air to the circulation spaces and building the air conditioning of the rooms and to the green gardens below.

Alternative prayer zones: Alternative prayer zones are also provided. The hotel towers have ramps within the central atrium that connects to prayer rooms located at every five floors. A prayer terrace on the roof of the concourse offers an alternative prayer area, a public open area shaded by buildings and palms planted around it, with a view to al-Haram.
The cooling tower also contains a pedestrian ramp, which both connects rooms to praying halls and continues into the lower retail areas delivering cooled air from above. In addition, planting and water ponds are placed on the tower roof to cool the intake air and reduce the amount of air-borne dust. The roof gardens also form major prayer areas, with views to al-Haram on the eastern tips and edges of the plan.

Coupled with the major evaporative cooling tower feature are Yeang’s principles of the green skyscraper, which he relates to the whole project.

The tower design incorporates a range of spaces for the offering of prayers, varying between the private room to prayer halls and terraces through to the al-Haram plaza praying area. Pedestrian travel in the service of prayer, is fundamental to the project and Yeang has studied this in great detail. Central to this key function is the inclusion of a promenade at concourse level:

"... the prime function of this Promenade is to serve as a collector for the Jabal Omar population as they are called to prayer five times a day. All of the population will be brought to this level, through the lift cores of the towers above or the escalators that link the four levels of the concourse... the population is divided into four streams, to be discharged at the plaza below by chutes consisting of escalators and travelators.”

Having established these major pedestrian movement systems, which bridge the Ibrahim Al-Khalil Road, to deliver pilgrims in safety to the precinct of al-Haram, Yeang has also provided an analysis of pedestrian travel time. This study proves the success of the development and "... the speed at which the population can access the praying areas for their daily devotion.”

As with all Yeang’s projects vertical landscaping is incorporated at intervals, particularly in relation to prayer rooms in this instance.

The overall plan-forms of both hotel and apartment towers are organic in nature, and have something of the quality of Hans Scharoun, at first sight. Looked at in detail, the design of each room and linear cluster is dominated by the provision of outward vistas to al-Haram, which are provided by faceted glazed walls to the leading edge of each unit.

Seen as a whole, the Jabal Omar project exemplifies the comprehensiveness of Yeang’s design method which covers the whole range of considerations from the making of a new city area to the careful design of the individual room. In turn his ecological approach, the regeneration of landscape and the organisation of movement are gathered together to form an urban sanctuary which exists to serve pilgrimage and the purpose of the pilgrims’ offering of prayers.
The Jabal Omar site forms one of five hills that surround the holy site of al-Haram. As such, it is the outer rim from which views of the praying area can be seen. The scheme seeks to make use of the elevation of this outer rim, developing a viewing and praying concourse along the crest of the hills.

The roof of this concourse contains praying areas within a landscaped garden. These praying areas form an extension to the praying platform below, whilst still allowing for the development of the lower slopes. The concourse at Level 2 also serves as the main drop-off level for those arriving by vehicles.

Below the concourse at Level 1 is a service road to meet all deliveries, refuse disposal and service requirements. The concourse consists of four levels of commercial activity, which face the Haram. It encloses the reception areas for the towers above and acts as a collect point for the population of Jabal Omar and the adjacent areas from which people will be taken to their prayers along two major chutes extending into al-Haram.

There are two factors that would suggest that the development of the surrounding hills of the Haram would create a harsh, desert-like concrete jungle. The climate of Makkah is hot and dry, with little vegetation. Due to the large numbers of pilgrims, especially during the hajj times, the densities required to accommodate the resident, commercial and temporary populations are extremely high. However, careful planning and the sensitive treatment of an indigenous ecosystem can encourage vegetation to grow, providing a greened and ecologically friendly environment in which to house the pilgrims.

If taken throughout the enclosing hills the greening of the rim will create an oasis, containing and enhancing the prominence of the Ka’bah.

The design concept can be taken throughout the five hills of Makkaah creating an enclosure to the holy site that allows for accommodation and commercial activity within its boundaries.

The above are the key features that make this scheme environmentally responsive and unique.
The development consists of a series of towers above a concourse at the feet of the hill. With the density maintained on the site, high rise buildings are inevitable.

The towers are designed above a concourse which collects the circular on and off traffic and channels the population flow to the praying place.

The towers are configured to fulfill the requirements of the site; primary provision of a clear view to the Haram, easy access from each apartment or room and from the concourse edge. The shape of the towers is reminiscent of an open book as a constant reminder of the Koran

The concourse is served by a main distributor road with a service road for deliveries running beneath it.

As the Haram is the primary focus of the site, the design should ensure that the area is visible from each apartment.

The promenade is assumed as a view of al-Haram from the roof that gives a view to the sacred place. A hierarchy of views exists in Makkah; the Ka'bah is the prime focus. During the holy season when the site is covered with pilgrims the secondary visual zone extends to the edges of this plaza.

The landscaped roof garden offers a view to al-Haram so that outdoor prayer areas from the promenade.

The Promenade as a 'collector' to chutes to al-Haram

The main level of the concourse has a generous promenade area that connects the site from the adjacent sides to the north and south. The promenade has views of al-Haram and the praying platform that surrounds it. It is continuously serving the people within the concourse to the focus of these pilgrims.

The prime function of the promenade is to serve as a collector for the large number of pilgrims who are called to pray five times a day. All of the population will be brought to this level through the left corners of the towers above or the escalators that link the four stairs of the concourse.

The population is divided into four streams to be discharged at the plaza below by chutes consisting of escalators and elevators.

Site cross-sections

\[\text{Diagram of site cross-sections}\]
A cooling tower, located near the center of the high-rise complex, provides a cooling and dehumidification system to help maintain a comfortable indoor climate. The tower sends chilled water through the building to be used for cooling, and then returns to the tower for reuse.

The design of the cooling tower takes into account energy efficiency and environmental considerations. The tower is constructed using materials that are durable and require minimal maintenance. In addition, the design incorporates features that help reduce energy consumption and environmental impact. The cooling tower is an essential component of the overall sustainable design of the high-rise complex.
The development is oriented towards the east, to maximise the views of the Masjid that are available from the Al-Shaikh Omer site. As a result, these facades are exposed to the morning sun and, to some extent, to the mid-day sun from the south. Although the height of the towers implies a degree of privacy, the Roshan details serve for both screening and shading purposes.

The Roshan are made of a mixture of metal and timber. Web is used to integrate with the traditional elements of the city, and to soften the facades.

The western facades are solid, with narrow slit windows to isolate the buildings from the wet afternoon sun.

**tower C**
- Wind scoops
- Roshan
- Prayer rooms
- Sky courts
- Ramps from hotel rooms to prayer halls
- Sky courts
- Sky gardens
- Ramps from roof garden to concourse
- Prayer gardens

**tower D**
- Wind scoops
- Roshan
- Prayer rooms
- Sky courts
- Sky gardens
- Ramps from roof garden to concourse
- Prayer gardens
The Promenade as a ‘collector’ to shrines to Al-Haram

When the Holy Mosque is the focal point at the center of the prayer areas it is by either the tombs through the central portion to the entrances that descend between either at the prayer rooms, the tomb prayer areas or at the main concourse. The concourse is connected to the parking areas by bridges.

Movement between the concourse and the main concourse is through elevators.
The prayer access from the concourse to Al-Haram is via the plaza for entrance and car-parks. Throughout the concourse there are entrances to serve the parking facilities.

Proposed landscaping zones and major planting groupings

Zone A: Front slope landscaping

The slopes range in elevation from 256 m to 279 m and form a major open space facing the holy mosque. Here a single space palms is proposed to dominate the slope with planting distance about 6 m apart. The planting zones could be edged in rocks with ground cover planted on top of the planting zones.

Palm: Phoenix dactylifera

Ground cover and low shrubs: Kandura camera bougainvillea Duranta repens

Zone B1: Rooftop planter and connecting walkways

The planting on this zone will serve as ornamental as well as functional - shade palms, ornamental flowering shrubs and sweet-smelling night blossoms to mitigate the isolated spaces between the buildings. The planting of this area will be in a series of raised planters with gravel on top for shade as well as for shrubs. Also present in the area are other landscape planting elements such as walkways, paving for prayer areas, water points and seating areas.

Palm: Phoenix carica, Phoenix dactylifera

Washingtonia robusta

Shrub: Parkinsonia florida, Phormium tenax, Ilex aquifolium, Phormium tenax, Myoporum sandwicense, Casuarina equisetifolia, Bougainvillea spectabilis, Alternanthera, Xerox unedo, Datura ferox, Bocconia frutescens, Lysimachia nummularia, Cynanchum grandiflorum, Elaeagnus angustifolia, Amaranthus caudatus, Caserioa odorata, Plectranthus fruticosus, Euphorbia dendroides, Lantana montevidensis

Zone B2: rooftop planter and connecting walkways

Cascading planters facing the holy mosque will be planted with taller Bougainvillea to give Zone B2 a monumental, picturesque and connecting walkways; a variety of plants and trees will be planted facing the mosque to create a softening effect. The planting on this zone is similar to Zone 3; interest here is on landscaping that is monumental with more space and views forming the back of the open spaces instead of the “greening varieties of 3’"
vertical urban design
vertical urban design
The MAX Tower project has significance in Yeang's work, not just because it stands in the realm of his 'green skyscraper' series, but that it also marks his entry into a range of European commissions, that have subsequently advanced into the UK itself. This advance not only brings his architecture into a new and receptive marketplace, but also presents the context of a completely different climatic condition, from that of his major range of projects in the Far East.

The tower and its site stand very close to Norman Foster's landmark Commerzbank in Frankfurt, which is highly appropriate as both designs are part of a new tradition of environmentally conscious architecture.

Within the context of Yeang's work, the MAX Tower plan is markedly different, for in this case the service cores are inboard and form two sides of a square atrium, which rises through the whole-form as part of its environmental strategy, and brings natural light to both offices and circulation depending on the internal arrangement. The peripheral office space, encircling the core of services and atrium, is a regular band of 15 metres in width, which facilitates a whole array of optional internal space arrangements and a high degree of natural day lighting. Variable office groupings can also be inter-linked by a system of ramps, which cross the atrium void, at intervals. The office plan form therefore an efficient, rational overall arrangement incorporating great flexibility and variety of occupant orientation and outward views over the city.
The building in general is technologically sophisticated, and includes a variety of systems and details, such as a double-skin facade and the use of photovoltaics, contributing to its energy-efficient content.

However, the aspect of the design which is at once most evident, and has the greatest impact on the architecture, is the *greening* of both the site and overall building form and its interiors. This is particularly evident in the section and on the facades, where an extensive system of fully landscaped skycourts are linked vertically by a spiralling range of planted inserts. While this is common place in Yeang's work as a whole, it becomes a remarkable event in the context of the high-rise in an European city. As such, it openly exhibits the qualities of the 'green skyscraper', and the very different nature of the environment offered to its occupants.

Yeang's approach to this transformation begins at ground level, which is designed as a green park with the continuous vertical planting on the tower running from street level to the summit. In establishing a stable ecosystem, it is Yeang's stated intention "... to balance the inorganic aspects of the city environment ... with more organic mass". Coupled with this, earth mounds and recessed courtyards are included at the base of the building to assist integration with the ground form, and natural light and planting penetrate into the basement car-park through skylights punctured into the park. Within the extensive facilities of the spreading, linear street-level podium Yeang has formed a public plaza, with a glass enclosure that provides a "greenhouse environment" — controlled by operable windows and walls. This space — a form of winter garden — provides an all year facility and appropriate to the variable seasonal climate.

As well as the general overall provision of planted skycourts, balconies and viewing decks, in this case Yeang has also provided a form of *localised skycourt*, serving clusters of office space, with movable internal planting. These skycourts have *adjustable shutters*, which provide control for the associated office space, depending on the seasonal conditions, and the comfort conditions required by the occupants. This device, which is illustrated in a series of plans demonstrating the variables is particular to this project and again, extends the principle of the *winter garden* idea, an urban tradition in German cities such as Frankfurt and Berlin.

Yeang's proposition for the *green skyscraper* in the European context both contains the landscaping within its internal space and offers this literal greening to the city on its exterior. The tower architecture is transformed to a vehicle of organic inhabitation — an ecological symbol.
conference room inserted as peas in a pod
At the very centre of Yeang's proposals for the Nagoya 2005 World Exposition, lies a clear commitment to the preservation of the ecosystem of the locality. Instead of adopting a conventional horizontal layout for the Expo, which would spread over most of the 150 hectares of site area, Yeang has proposed a vertical alternative, with a building footprint of just 2 hectares occupied by a 50-storey Hypertower of 12 metres per storey, rising to 600 metres in height. This solution effectively creates "artificial land" in the sky, as each platform of the mega-structure can be occupied by the various Pavilions, that form the World Exposition.

The overall proposal is thus framed in two fundamental ideas: that of a vertical mega-structural system interfaced with a series of concepts, and a set of optional vertical circulation systems. This proposition is generated entirely, by a direct response to the theme set out by the Expo 2005 Committee for the Exposition i.e. "... express the need to reconsider the natural world through the adoption of an innovative attitude to urban planning, infrastructure, building design and information, proposing new standards for quality of life in an ecologically friendly environment."

Yeang's competition proposals, which were submitted under the Sponsors main headline of "... Beyond Development: Rediscovering Nature's Wisdom" were underscored by a clear statement of indisputable advantage: "... in going vertical, the proposal will preserve more than two-thirds of the existing ecosystem of the locality ... (and) will therefore avoid extensive land clearance and disruption to the site's existing mature ecology." The design proposals are based on a distribution of within the 50 segments, with a mix of horizontal and vertical zones.
Japan, covering 378,000 square kilometers over the four main islands (Hokkaido, Honshu, Shikoku and Kyushu), lies mostly in the temperate zone and has a humid monsoon climate. Extending over 25° of latitude, there is considerable variation of temperature with Hokkaido in the north registering a winter mean of -3°C and Okinawa in the south experiencing a summer mean of 28°C.

With a population of 125 million, Japan also has one of the world’s highest densities at 335 persons per square kilometer (USA at 28 persons per square kilometer) with a rapidly diminishing resource of arable and habitable land.

One of the simplest way to accommodate high densities and yet preserve nature and to avoid building over valuable arable land (eg. rice fields) is to go upwards. This is a critical issue which needs to be addressed not only in Japan but worldwide. The Expo 2005 becomes an ideal platform for this debate and re-assessment of existing attitudes and ideas regarding intensive buildings. The proposal here offers the ‘vertical’ solution to these issues.

Infrastructure of Seto City, Aichi Prefecture

Aichi Prefecture is home to the city of Nagoya, one of the three largest metropolitan areas in Japan. Its central location gives it convenient access nationwide. Nagoya is the important mid-point along the shinkansen line running from Tokyo and Osaka. The Meishin Expressway connects Nagoya to Osaka while the Chuo and Tomei Expressways links it to Tokyo. The ports of Nagoya and Toyohashi serve the region with a proposed new international airport in Chubu further enhancing and ensuring the future growth of this area.

Satoyama woodlands

Seto which is 20 km south-east of Nagoya has a 1,300-year history as a ceramics center. During this time, the land was mined for the native clay and trees logged to fire up the kilns. This exploitation of the local natural resources resulted in a ravaging cycle of deforestation and reforestation which peaked in the 1940s and lasted until recently.

With a heightened awareness of forest conservation, switching to other sources of fuel and an ambitious reforestation program, the area is now rehabilitated into a viable mixed-growth mature forest habitat. The site is a maintained ecosystem referred to as the satoyama woodlands. The illustration here shows the results of successful ecological succession in which re-vegetation and reforestation has taken place over a formerly devastated site.

Flora and Fauna of Aichi Prefecture

The Satoyama Woodlands together with the Kechi Forest on the outskirts of Nagoya are the habitat for a diverse collection of valuable plants, birds and insects. Over 800 species of plants live in these forests.

A recent research surveyed 61 species of butterflies, 41 species of dragonflies, 300 species of moths, 121 species of birds, 15 species of amphibians and reptiles, many of which are rare and endangered. For example, the magnolia stellata (star magnolia) found here, grows in less than 100 areas around Japan. The goshawk (Accipiter gentilis), also lives and breeds in this area. This species is particularly rare in Japan as its natural habitat continues to disappear. Another species at risk is the girucho butterfly (Hedychrum japonica) which is endemic to Japan.

This proposal for Expo 2005 aims to proactively address the preservation of these indigenous species. A vertical Expo layout over this site will without doubt eliminate many of these valuable species

the viable alternative to the "horizontal" expo

The modern expositions of the last two decades generally composed of low-rise purpose-built or proto-typical pavilions laid out over a large site and is usually connected by a vast transport network of rail, road and sometimes marine craft systems. The impact of a horizontal built-form on the site is evident. It will result in widespread destruction of this mature ecosystem.

In pursuing an alternative layout and specifically to minimize the impact of the built form on the existing woodlands and the indigenous wildlife, the traditional expo masterplan is re-interpreted and re-organized in a "vertical" configuration. The comparison of the built footprint on the locality is illustrated below. Clearly the "vertical" solution is much preferred over the "horizontal" one as it will have a smaller footprint on the ecologically mature site.

Satoyama woodlands

The comparison of the coverage of the built form between the horizontal and vertical planning concept is as follows:

<table>
<thead>
<tr>
<th>A horizontal Expo 2005 Development</th>
<th>B vertical Expo 2005 Prototype Tower</th>
</tr>
</thead>
<tbody>
<tr>
<td>• total area of site = 540 ha 100.0%</td>
<td>• total area of site = 540 ha 100.0%</td>
</tr>
<tr>
<td>• proposed area of development = 75 ha 14.0%</td>
<td>• proposed area of development = 75 ha 14.0%</td>
</tr>
<tr>
<td>• area reserved for natural environment = 495 ha 86.0%</td>
<td>• area reserved for natural environment = 495 ha 86.0%</td>
</tr>
<tr>
<td>• increase in area for natural environment = 147 ha 18.0%</td>
<td>• increase in area for natural environment = 147 ha 18.0%</td>
</tr>
</tbody>
</table>

reduced footprint on ecosystems
Essentially this allows horizontally zoned pavilions to be located in one or more of the vertical 12 m spaces, or for vertically zoned pavilions to occupy a multiple of levels – such as the International Pavilion or the Japan Pavilion.

The major plan arrangement – an interlocking U- and L-formation – is configured to incorporate a multiple set of systems. Most important amongst these is a spiralling monorail with twin tracks set on the tower's periphery, and with stations at frequent intervals, the whole connected to the LRT at the ground plane. This basic system is supported by elevators, escalators and inclined travelators. A further pedestrian promenade is included, between pavilions, by a large gentle ramp that continues from the ground plane to the summit of the tower.

In certain respects there is a similarity to Yeang’s earlier proposals for the Tokyo Nara Tower, for instance in the Nagoya Tower’s vertical landscaping strategy, and in the nature of its triangular mega-structure and horizontal cross-bracing. However, in this case, the especially different elements are the structural floors which form foundation plates for construction in each vertical zone. Equally, Yeang has given specific instances of how the zoning might be applied: in the horizontal case, office administration, light industry, residential units and urban infrastructure are proposed, in the vertical case exposition pavilions, hotels and commercial units are applied volumes.

To this mix is added a host of facilities including an arts and crafts village, convention hall and theatres. The main U-form of the curved plan is orientated to acquire views and natural light, with vistas that include Mount Fuji itself, and the Nagoya bay Ise Shrine.

As with all Yeang’s projects there is a major emphasis on this as an ecological architecture: “... the building’s operational and environmental systems will address the challenges of the new century giving respect to nature in a technological response, using clean and efficient energy technologies and recycling systems.” The project, he proposes, can also be seen as a model for future urban expansion, such as the relocation of the Japan Government facilities outside Tokyo.

This project, in its deliberate and sensitive response to the local ecosystem is at one stage beyond all Yeang’s previous proposals. It is not just a proposal for a Hypertower, but a signal initiative which addresses the nature of a whole region. Its deserves to be built.

The Expo 2005 Tower is the alternative proposal as the 'vertical' option to the conventional horizontal layouts used in previous international expositions. This supports the goals for Expo 2005 in addressing the concerns of the environment and the world’s burgeoning population.

In addition, the ‘vertical’ solution here is in line with the Expo’s aims to develop a new mutually respecting relationship of nature with mankind and technologies related to the protection of the environment as well as the preservation of the Satoyama Woodlands.

The proposal for the ‘vertical’ expo is ecologically further enhanced as it sets on the proposed platform links over the proposed expressways (which will boost the woodlands) as foreclosed bridges between the adjacent woodlands. These connections (interspaced with generous lightwells) may establish ground level migration routes and encourages species migration between each micro-habitat. This engenders a more stable ecosystem and enhances the ecological diversity of the immediate site and the surrounding Satoyama Woodlands.
**EXPO promenade**

The main feature of the Expo 2005 tower will be the gentle vertically accessible promenade which provides access to all the pavilions, public areas and facilities.

The pedestrian promenade takes the form of a continuous loop, ramp, and stairs, allowing the grass and the ground plane to the top of the tower, weaving together the different parts of the tower where secondary streets and public squares may extend off the public realm.

The promenade loop have points of intersection that offer a potential territory of dynamic urban interaction, activities and exposition-related ceremonies.

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**vegetation strategy**

As the 2005 Expo is held over the summer months, the weather would be ideal to enable the profuse use of local plant types and strategic landscaping within the tower.

In addition to decorative and ceremonial uses, vegetation becomes an integral part of the external facade system for sunshading and micro-climatic control (particularly the hot east and west sides).

Pockets of foliage are placed at regular intervals along the entire height of the tower, will serve as green lungs refreshing the environment, improving the air quality and provide:

1. vegetation on the facade for sunshading and micro-climatic control
2. decorative landscaping along the main exposition promenade
3. vegetation pockets located in public areas as natural air fresheners

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**primary circulation system**

A continuous (entire) mass transit light rail transit (LRT) system links all the main zones in the tower with regularly spaced stations at the levels of the tower.

Together with banks of high speed lifts, these will provide the primary rapid transit system for the anticipated crowd of visitors to the tower.

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**secondary circulation**

The secondary circulation system provides the links between each of the three pavilions using secondary district lifts, evacuation paths, escalators, ramps and staircases.

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**tertiary circulation**

The tertiary circulation system provides connections with each of the pedestrian using local lifts, "skin crawlers", ramps and staircases.

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**quaternary circulation**

The quaternary circulation system provides local more than links using gondolas, local ramps, and staircases.
The key circulation system is by means of a monorail (Skybeam Rapid Transit - SRT) with two monorail tracks placed on the periphery of the tower with stations at three segment intervals for two minutes (traveling time between stations). This connects to the LRT system at ground plane.

In addition, the vertical prototype 5900 Tower will have a three dimensional transportation system that is structured vertically and horizontally for high speed mass transportation as well as for personal transportation. Circulation within the Tower is structured in a multi-tiered hierarchical system.

**primary circulation**

- function: links all major programmatic zones in hyperzone
- features: continuous SRT system with fully automated monorail twin tracks integrated SRT stations at every three segments (36 m) high speed SRT that connects the entrance to major pavilions

**secondary circulation**

- function: circulation between hyperzones (15 segments separated by refuge zones)
- features: dual rail that connects refuge zone evacuation routes within each hyperzone that terminates in the refuge zone

**tertiary circulation**

- function: circulation within each hyperzone
- features: local lift that serve every segment skin crawlers that links at every 3-5 segments

**quaternary circulation**

- function: inter-segment circulation
- features: continuous gondola system that runs between three segments continuous ramp and travelator systems that run through every segment
The tower will be 300 meters high and will have 25 segments of platforms @ 12m height that will enable the various pavilions to be built (up to three storeys) within each segment. The tower's distribution of land use within the 25 segments will be on a "horizontal" and "vertical" zoning basis.

"Horizontal" zoning applies to individual pavilions (e.g., country, corporations, NGOs) and facilities which are located within one or more of the 25 segments of 12m height. "Vertical" zoning provides for certain pavilions and facilities to be accessible from all floors (e.g., the Expo Theme Pavilion, the Japan Pavilion, Special Forest Pavilions, services and security).
In contrast to the conventional stratifications of floor uses, the Expo 2005 tower has both horizontal zoning of uses as well as vertical zoning. Some uses are linked vertically and are on all floors.

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<tr>
<th>zone</th>
<th>areas (in sq m)</th>
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<tr>
<td>1   expo 2005 pavilions</td>
<td>200 000</td>
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</tr>
<tr>
<td>• international zone (exposition pavilions)</td>
<td></td>
<td></td>
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<tr>
<td>• local government zone (Japanese pavilion)</td>
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<tr>
<td>• theme pavilion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>• arts and crafts village (theme zone)</td>
<td></td>
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</tr>
<tr>
<td>2   hotels and commercial</td>
<td>188 000</td>
<td>8.4%</td>
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<tr>
<td>• convention hall</td>
<td></td>
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<td>• theater</td>
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<tr>
<td>• event theater</td>
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<td></td>
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<tr>
<td>• guest house (residential units)</td>
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<tr>
<td>3   office and administration</td>
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<td>20.7%</td>
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<td>• international organisation zone</td>
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<td>• administration (offices), security, medical</td>
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<tr>
<td>• gate facilities</td>
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<td>• pedestrian road</td>
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<td>• bus terminals</td>
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<td>• main approach from railway</td>
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<tr>
<td>• main approach from bus</td>
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<td>• moving walk</td>
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<td>total built area</td>
<td>2 230 500</td>
<td>100%</td>
</tr>
</tbody>
</table>
The fundamental feature benefit of the vertical solution is that it will have a significantly smaller building footprint at the ground plane (i.e., 3 ha compared to that of the horizontal version at 75 ha). The vertical Expo will therefore avoid extensive land clearance and disruption to the site's existing mature ecology. In exploring one of the Expo’s goals of ‘environmentally creative town planning’, the Expo 2005 Tower is laid out essentially as a ‘city in the sky’ thereby bringing together all the elements from a conventional horizontal urban structure (e.g., transportation network, commercial and residential components, services and amenities, utility systems, recreation zones, public facilities and spaces, etc.) and reconfiguring them in a vertical layout. This will substantially free the forested ground plane from ecological damage and disruption and a much-preferred handling of the existing Satoyama Woodlands.
The natural light is maintained at a maximum depth of 30 m to ensure natural light penetration into the interior display space. The guideline light also maximizes the external surface area to optimum exposure to natural light and view opportunities. In addition, the generous external spaces provides spectacular panoramic views of the surrounding Sapporo Woodlands and the adjacent environs.

The design in effect provides artificial light within three-storey segments to enable users to construct three- to four-storey sub-buildings within the mega-structure. The project therefore has a 'long-life' and 'loose-fit' ecological justification.

Every segment allows for construction of 3 - 4 storey building.

International pavilion zone @ 25 segment

Continuous pedestrian ramp as main boulevard

Vertical Expo 2005 Prototype Hypertower

<table>
<thead>
<tr>
<th>Top Area of Site</th>
<th>Proposed Area of Development</th>
<th>Proposed Footprint @ 30 Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>5474ha</td>
<td>150ha</td>
<td>360ha</td>
</tr>
<tr>
<td>100%</td>
<td>7.1%</td>
<td>6.7%</td>
</tr>
</tbody>
</table>

Area Reserved for Natural Environment

11474ha | 21% |

Horizontal Expo 2005 Development

<table>
<thead>
<tr>
<th>Total Area of Site</th>
<th>Proposed Area of Development</th>
<th>Area Reserved for Natural Environment</th>
</tr>
</thead>
<tbody>
<tr>
<td>150ha</td>
<td>150ha</td>
<td>30ha</td>
</tr>
<tr>
<td>100%</td>
<td>100%</td>
<td>20%</td>
</tr>
</tbody>
</table>

The existing pristine ecosystem
Each 12 m floor to ceiling segment height (refer to illustration below) will allow up to a three-storey garden construction with an independent quasinary circulation system. This space will then be converted into 'real-estate-in-the-sky' after the Expo 2000.

The space allocation is comparable to the land use apportionment of Expo '98 in Lisbon. The expected population density is estimated as follows:

- Estimated visitor population
  = 12 million / 6 months
  = 2 million/month
  = 64,500 visitors/day

- Estimated staff population
  = 20% of visitor population
  = 12,900 staff

- Estimated population in tower
  = about 77,400 per day during Expo
In the design of the tower, it takes the form of a fully automated mechanical SRT (Special Rapid Transit) system. The system involves the division of passenger zones into a large public area where intermediate floors and public squares are included off the public track. The SRT system consists of a pair of reverse track lines for access from the upper floor. A multiple complex of three segments at 16 m. SRT stations are placed at every three segments, providing access via platform elevators and doors.

SRT stations in every 3 segment intervals
Total stations = 18

Transfer Floor

Segment 1

Segment 2

Segment 3

The main station located at segment 3 is connected to the Main City Transport Line.

Main City Transport Line
These projects, which are both centred on residential accommodation and mixed-use, and are both the subject of competitions, mark Yeang’s entry into the UK scene, with proposals for two major locations in the city.

While the development briefs and sites vary in detail, both are essentially configured as a range of peripheral towers with a centralised facility, such as market square or transport interchange and plaza within the site. Both projects are associated with railways tracks, which are in boundary or centralised positions. Logically, as both projects are located in London, either north or south of the River Thames and have similar programmes with the emphasis on residential use, Yeang has applied similar concepts, criteria and methodology to each scheme. These factors of the designs exhibit the characteristics of Yeang’s ‘green skyscraper’ and vertical urbanism propositions.

Yeang’s approach is based on three major issues and their incorporated resolution. These include Social Sustainability, Environmental Sustainability, and Passive Low Energy Responses, and expanded in detail these form the overall framework and content of the projects. Yeang’s controlling concept of the ‘City-in-the-Sky’, recurring in almost all of his high-rise work, envisages the skyscraper “... seen as a microcosm of the city, containing within itself the inherent elements of a city block ... parks, shops, entertainment centres, community facilities, social housing” ... ¹ and other residential accommodation types.

Yeang then outlines the benefits of this intensified vertical urban condition, which includes local employment resulting from mixed use, a balanced mixture of residents depending on income and accommodation requirements, yet with common facilities, such as parks and shopping streets provided on a shared basis. The arrangement then allows for basic amenities such as local stores, postal boxes, chemist and so on, to be provided within the building. Further, and characteristically, Yeang emphasises the creation of a healthy landscaped environment, with

“... spatial progressions of public open spaces (parks in the sky) to semi private (entrance courts) to private open spaces (balconies).” ²

In the case of both projects Yeang’s agenda for Environmental Sustainability is identical, and is drawn directly from his ‘Green skyscraper’ treatise, and his open general systems framework. ³

This includes the interconnected set of external and internal interdependencies, together with the external-to-internal exchanges of energy and matter and vice versa, the designed systems output of energy and materials. To this Yeang then adds the considerations of Passive Low Energy Responses, both by Building Configuration and Orientation, and by Landscaping and Vegetation. Thus both designs, although varied in detail, are based on Yeang’s full agenda for an ecological architecture, in this case related to the temperate climate of London.

From this shared conceptual basis, the two projects can be reviewed independently, within a closely related typology.
The Bishopsgate Towers include two 65-storey residential skyscrapers, and a 50-storey office and hotel associated with a convention centre.

The residential towers are sited on the southern edge of a new Market Square, which includes a linear shopping complex with retail outlets, cafes, restaurants, arts and crafts centre and studio workshops, forming a new cultural hub for the neighbourhood.

The residential towers share a common plan-form, which has a radial configuration with the apartments forming a 'fan' arrangement on the northern and southern faces. The peripheral accommodation encloses an internal atrium, which rises through the building surrounded by a continuous landscaped ramp. This primary pedestrian circulation forms the principal element of the towers, which are essentially radial-spiral forms. The landscaping of the atrium is augmented by planted facades and terraces, which collectively contribute to the rehabilitation of the site, which Yeang describes as a devastated ecosystem.

The mixed-use facilities extend over several levels, from the base, and occur again at vertical intervals such as level 23, which Yeang describes as a High Street, with shops, cafes and pub.

Taken together, the range of mixed uses proposed is extensive, and Yeang has assembled this into a horizontal and vertical zoning diagram, which controls the occupation of the multi-layered and multi level zonal masterplan of the entire building, conceived as a vertical land use pattern. This includes car-parking, vertical services, landscape, retail, housing and circulation. The building itself includes both social/subsidised and private apartment accommodation, which provides each unit with a planted terrace/garden throughout a range of various plan-types.

As thoroughly conceived 'green skyscrapers,' these buildings exhibit all the major systems of Yeang's ecological design method, similar in principle to the EDLIT tower, but modified to a temperate climate with sustainable objectives applied to a high-density scheme. Outstanding amongst these design studies are Yeang's passive low energy responses. Characteristically, the overall form is governed by the supports of the site, and the conditions of the summer and winter windrose.

Essentially each tower is configured as two blocks with a weather-protected landscaped core. The buildings are orientated...
In this case, the lift cores are positioned on the north-east and west facades, providing a buffer of solar protection in summer. Conversely, during the winter months, low-angle sun can penetrate to the landscaped circulation atrium, and south-east facing residential units receive maximum solar gain. Beyond these basic principles, Yeang has applied special attention to the facade design, and the relationship of this, in particular, to the residential accommodation.

Essentially the facade is designed to allow maximum light into the interior spaces, while excluding cold winds by the use of a multi-layered external wall, which controls both the individual garden terraces and living units. This detailing includes both mesh-screen wind-breaker elements that reduce the inflow of strong winds, together with adjustable, insulated shutter doors that retain internal heat at night. This arrangement is then supported by both large double-glazed windows and internal shutters. Finally, there is the contribution of the landscaping and planting of private gardens and communal sky-parks, that both acts as a wind buffer, and in summer as protection against solar radiation.

Seen as a whole, the detail design of the residential unit types - such as the three-bedroom duplex, which incorporates ramps between levels - all contain a great variety of articulated spaces and innovative installations, and are flexibly suited to all occupier categories.

While Yeang has typically expanded many other overall design considerations, such as the ventilation variants incorporating the central atrium, the use of south-facing photovoltaic panels as a rain-screen or the rainwater catchment scallops - all part of his green agenda, it is the additional detailed design of the residential elements that particularly marks this project. In turn the careful consideration of occupation and lifestyle contributes a further level of content to Yeang's ecological architecture.
Ecological design starts with looking at the site's ecosystem and its properties. Any design that does not take these aspects of the site into consideration is essentially not an ecological approach. A useful start is to look at the site in relation to an 'hierarchy of ecosystems' (see right).

From this hierarchy, it is evident that this site is an urban 'zero culture' site and is essentially a devastated ecosystem with little of its original top soil, flora and fauna remaining. The design approach is to rehabilitate this with organic mass to enable ecological succession to take place and to balance the existing inorganicness of this urban site.

The unique design feature of this scheme is in the well-planted facades and vegetated terraces, which have green areas that approximate the gross usable-areas (i.e. GFA @ 42,820 sq m) of the rest of the building. The vegetation areas are designed to be continuous and to ramp upwards from the ground plane to the uppermost floor in a linked landscaped ramp. The design's planted areas constitute 40,700 sq m which is 9:1 of gross usable area to gross vegetated area.

<table>
<thead>
<tr>
<th>ecosystem hierarchy</th>
<th>site data requirements</th>
<th>design strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>ecologically mature</td>
<td>complete ecosystem analysis and mapping</td>
<td>preserve, conserve, develop only on low impact areas</td>
</tr>
<tr>
<td>ecologically immature</td>
<td>complete ecosystem analysis and mapping</td>
<td>preserve, conserve, develop only on low impact areas</td>
</tr>
<tr>
<td>ecologically simplified</td>
<td>partial ecosystem analysis and mapping</td>
<td>increase biodiversity, develop on low impact areas</td>
</tr>
<tr>
<td>mixed artificial</td>
<td>partial ecosystem analysis and mapping</td>
<td>increase biodiversity, develop on low impact areas</td>
</tr>
<tr>
<td>mono culture</td>
<td>partial ecosystem analysis and mapping</td>
<td>increase biodiversity, develop in areas of non-productive potential, rehabilitate ecosystem</td>
</tr>
<tr>
<td>zero culture</td>
<td>mapping of remaining ecosystem components (e.g. hydrology, remaining trees, etc.)</td>
<td>increase biodiversity and organic mass, rehabilitate ecosystem</td>
</tr>
</tbody>
</table>

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**Sky Park**

**Gardens**

Vegetation from park level is spiralled up the building as a continuous eco-system. This facilitates species migration and engenders a more stable eco-system.

**Key Plan**

**Circulation System**

- Primary Vertical Circulation
- Tertiary Circulation Lift
- Primary Circulation Ramp
- Secondary Circulation Stairs
- Primary Circulation Ramp into Building
Photovoltaics can be used to achieve greater energy cell sufficiency.

An assessment of the environmental options for the two 50-story mixed use residential towers are as follows:

### Annual building energy use

<table>
<thead>
<tr>
<th>Type</th>
<th>Area (kW)</th>
<th>energy (kWh/yr)</th>
<th>Annual energy consumption (MWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Building</td>
<td>22,290</td>
<td>2,200</td>
<td>1,160</td>
</tr>
<tr>
<td>Total</td>
<td>86,500</td>
<td>350</td>
<td>2,160</td>
</tr>
<tr>
<td>Solar</td>
<td>1,645</td>
<td>1,745</td>
<td></td>
</tr>
</tbody>
</table>

Figures based on *Good Practice* energy use in the building from its owners.

### Installation of PV cells in SE facade

- Optimal positioning of PV cells: South oriented, tilted at an angle of 30°.
- For this project, either cover the whole SW facade of the inclining angle (as shown on sketch diagram) or cover the whole SW vertical face of the building envelope, tilted at 30° angle, as shown on the diagram presented (panel lines placed on low level of each story for the whole facade).
- Taking the second case, as the one covering a larger area, total area covered 31 m x 5 m x 50 (stories) = 775 m².
- Potential power output, assuming PV cell efficiency of 13%. 100 kWP (10W peak). 100 kWp x 100,000 = 10,000,000 W peak.
- Potential energy generation from an 100 kWP source, assuming no shading from surrounding buildings, optimal orientation and optimal angle of 30° to the facade. Allow allowance to surrounding buildings and actual presence of points (0 if not shaded by the facade). 100 kWP x 365 days x 24 hours x 7.5 kwp = 3,075,000 kWh.
- This represents 3% of the total building load.
- Net gain = 19,997,000 kwh.
- Cost estimate: £50,000,000, assuming the cost of panels as £3,000/kWh. 100,000,000 W peak.
- The payback period on the PV installation is in years of the life-expectancy of the units, making these installations an economic solution.
- However, this is presented as a demonstration of the possible two mode option for this building.
water recycling and purification

- housing total net area = 22,990 sq m
- shops and offices total net area = 8,660 sq m
- housing units breakdown
  - social housing: 41 units
  - subsidised housing: 28 units
- Market rate apartments = 109 units
- Total = 178 units

**building population**

a. housing population:

- Population @ 2 rooms (average) per unit x 2 persons per room = 712 persons

b. retail/commercial population:

- nett retail/commercial area = 8,660 sq m
- population @ 1 person per 10sq m net area = 866 persons

**c. total population (per tower)** = 712 + 866 = 1,578 persons

**water recycling**

Water self-sufficiency (by rainwater collection) in the tower is at 2.9%.

- Building population = 1,578 persons
- Water consumption = 60 litres/day/person
- Total requirements = 94,680 litres/day
- Total rainfall catchment area = 1,200 sq m (roof) + 500 sq m (scallops) = 1,700 sq m
- London average rainfall/annum = 593 m
- Total rainwater collection = 1,008 m³/annum
- Water self-sufficiency from rainwater collection = 1,008 + 34,558 x 100% = 2.9%

**water purification**

Rainwater collection system comprises of roof-catchment 'pan' and layers of 'scallops' located at the building's facade to catch rain-water running off its sides. Water flows through gravity-fed water purification system, using sand filters. The filtered water accumulates in a basement storage tank, and is pumped to the upper-level storage tank for reuse (e.g., for plant irrigation and toilet flushing). Mains water is only here for potable needs.

**raw (underground) water**

Another, topical, addition to the rainwater/greywater system could be the addition of a raw water. With London's deep aquifer water level nosing at an alarming rate it would be a responsible move to use some of this water for toilet flushing, etc. Investigations would of course be necessary to establish that a borehole could provide sufficient yield.

**Notes:**

- The nature of the building generally suits greywater reclamation quite well, although people's acceptance of using greywater may prove a barrier.
- Greywater can only be stored for a short time (it actually turns septic faster than greywater).
- The storage would therefore be based upon a 24-48-hour turnover, although rainwater could be stored separately for longer periods allowing for the volume that would be necessary in order to maximise the water captured from infrequent rainfall.
- It is estimated that the demand for greywater would be in the region of 31,000 litres per day for each of the two towers. A separate rainwater collection tank in the region of 3 x 3 m or equivalent capacity would be recommended in conjunction with the greywater storage of approximately 4 x 2 m and treated storage of 2 x 2 m.
passive low-energy responses

The design here starts by optimising all the passive mode opportunities (i.e. optimising the use of ambient energies at the locality in relation to the temperate climate). The passive methods used are as follows:

a. by building configuration

The building is configured as two blocks with a weather protected central landscaped core.

b. by building orientation

The building has been orientated to maximise solar gain into the interior spaces in winter and mid-seasons, and to maximise solar shading in the summer months:

- Lift cores are located at the north east and west facades of the building to provide solar protection in summer.
- During the winter months when the sun is low, frontal landscaped circulation area and south east units receive maximum solar gain.

c. by facade design

The facade is designed to allow maximum light into the interior spaces while keeping out cold winds, by means of a multi-layered external wall with:

- Wind breaker metal screen to reduce inflow of strong winds.
- Insulated shutter doors to retain building heat at night.
- Large double-glazed windows.
- Internal shutters.

d. by landscaping and vegetation

Vegetation and landscaping within the private gardens and sky-parks building act as wind buffer while giving users a more humane environment.

In summer, vertical landscaping acts to obstruct it reflects a high percentage of solar radiation thus reducing ambient temperatures. The damp surfaces of grass and soil will also contribute to a cooler and healthier building.

mixed mode concepts

The basic mixed-mode strategy employed here is to encourage natural ventilation during the summer and mid-season months when the outside temperatures are conducive, and in winter, to minimise energy losses and changing over to a mechanically assisted ventilation system.

The exterior facade for the apartment units is considered from both the bioclimatic as well as an aesthetic angle for the city of London environment. The facade is multi-layered. The outermost layer is a moveable wind shield of perforated metal mesh, which can be opened to improve ventilation when required.

Next are timber folding doors which may be shut or angled to keep the terraces shaded from the sun in summer yet allow views out.

The third layer is double glazing for improved insulation properties. And lastly, all apartments are specified with adjustable timber blinds for further heat insulation.

On a windy winter day, the wind shield is drawn but due to a low altitude of the sun, the rays penetrate the perforated mesh and on through the opened interior blinds.

On a cold winter's night, all movable layers are drawn, allowing higher heater efficiency.

On a breezy summer's day, the wind shield and glass doors are opened to allow breeze into the apartment while the timber folding doors allow only desired sun to enter through the opened glass doors, thus allowing the terrace to be enjoyed. The movable floor grating is also removed for outdoor cooling the metal mesh acting as sun shades.

On a hot summer night, all layers are open for maximum natural cooling and cross-ventilation.

energy & materials input: mixed mode concepts

[Diagram showing sunpath, windrose, building configuration, composite of buffer, mixed-mode system, and temperature graphs for mid-season, winter, and summer.]
social/subsidized housing - tower A

Legend:
- Single Bedroom Apartments
- 2 Bedroom Apartments
- 3 Bedroom Apartments
- Living Space
- Car Park
- Playground
- Service Core

upper park level

ecological program level

tower park level

ground level
A central park is located above the street level, accessible by landscaped ramps. The park and high-level planting on the towers serve as 'green lungs' for the locality. The park also extends as 'green fingers' into neighbouring plots through high-level bridge linkages, providing greater urban connectivity and providing safe vehicle-free pedestrian routes via bicycle lanes and footpaths.

Within the park are shops, recreational spaces, urban agriculture and plant nurseries (within glass house enclosures) and also an aviary at the base of the towers.

The park is continued up the towers via gradual spiraling landscaped ramps, making the transition from ground to tower as seamless as possible.
**structure**

by Rob Haynald Consulting Engineers (London)

The structural system for a building of this height is governed more by lateral than by vertical loads. This is because an internal frame with braced cores may not be the most effective solution for buildings of this height. It is often most efficient to engage perimeter structures such as the façade to provide bearing.

The proposed structural system has transfer floors at every (10th) 10th level of the building, which distribute the gravity loads out to the cores. The transfer beams can be continuous with the utility plant floors, so no lifting up valuable plant space. The cores would act as large baffle columns.

The true cores would then become the legs of the building. By varying the vertical loads out at the perimeter of the structure it is inherently more stable for lateral loads. Note that this means the two baffle columns of the building that truly are to be constructed from high strength reinforced concrete. 10th floor sections of core will be required for each core at the lower floors.

The configuration of frame made up of the four 'legs' and the transfer floors at every 10th level would then form the multi-storey building platform for hanging supporting the various shapes of floorplate and the sloping levels. These 10th-storey null floors would be built after the main frame, and could be modified to suit at a later date without disturbing the main frame.

The leg structure of frame would be diagonally braced and braced perimeter structures this way are difficult in London because of the large depths of clay. Floors for the building would be 40-60 metres long and to form a grid of supports triangles are likely to be as great. The largest of these will be required underneath each leg, proportionate to the area of the core footprint. The capping slab is several metres deep.

Not having a deep basement means creating the lateral load path diffused in the foundation, increasing the complexity of the columns. Continuous these piles groups lose in the existing railway lines while keeping these operations would be very difficult. Consequently the buildings are located so that all the legs are as far away from the rail lines as possible.

**specifications and ecological benefits**

sustainable life cycle

structure

- high tensile steel framing
  - enables mechanized point construction
  - facilitates speed and flexibility of building's useful life
  - high speed and efficiency of construction
  - light (reduced) structural load
  - enables larger spaces to be achieved

lighting system

- local, dimmable, and gaseous discharge and gaseous discharge and scarce

special attention to reduce embodied energy

- large windows to improve natural lighting

focusing on all structural elements for the benefit of the building's useful life

- high performance building (heating and cooling) costs

- high performance building (heating and cooling) costs

- high performance building (heating and cooling) costs

- high performance building (heating and cooling) costs

- high performance building (heating and cooling) costs
vehicular traffic and pedestrian routes

The main vehicular access for the residential zone shall be via the south, from Quaker Street. A new ramped bridge is proposed across the existing railway viaduct to the residential drop-off lobby.

The main vehicular access into the adjoining commercial site is via Wheeler Street.

car parking
Public and resident car parking shall be located in basements. The lowest basement level shall approximate the level of the lower rail track. Limited roadside parking is also provided on Slater Street.

The location of the new East London underground railway station within the site will encourage residents and workers to make journeys to and fro from this development by public transport. Coupled with close proximity to basic amenities within the site, it is anticipated that demand for car parking spaces in this development will be reduced.

pedestrian
The northern, western and eastern boundaries of the site are envisaged to be porous, allowing pedestrian easy flow into the retail and commercial areas within.

The design is 'pedestrian-friendly' and provides for easy and pleasant journey by foot and bicycle within and through the development.

The roof level of the existing goodsyard structure is a park, with high-level landscaped links to adjoining parcels and public parks.
The massive regeneration project for the Elephant and Castle includes three Eco-Towers by Yeang on the east, and a central transportation – railway interchange, with a further project by Foster and Partners to the west, surrounding a major plaza. The overall project also incorporates social housing, which is financed by revenue from the towers, intended for private ownership. As well as a huge shopping and leisure facility, and other communal provisions, the development envisages three major parks.

Yeang’s three buildings, known as the Garden Towers, represent his first competition success in London that may form a built proposition. In most major respects these towers, which vary in height between 12 and 35 storeys, repeat much of the concept of the Bishopsgate Towers, as a precedent. That is to say, that building configuration, orientation, façade design and landscaping policy directly reflect the earlier model. However, in this instance the lifts and staircases are brought together into a more compact arrangement, but again within a centralised, landscaped, access-galleried atrium. The typical floor-plan, for instance of Eco-Tower 1, is again a two-sided arrangement, which offers a variety of unit-orientation and outward views. To the overall form, in addition to the skycourts and apartment balconies, Yeang has added generous 'sky-pod' volumes for communal facilities and the summit incorporates a major winter garden, which outwardly signals the building’s ecological presence.

design features
- The Elephant and Castle regeneration project was jointly designed by a number of consultants. A new railway interchange divides the site into two. The west side of the railway track was designed by Foster & Partners and the residential apartments on the east side of the railway track by BRIM Architects.
- The central tower was designed by Yeang’s team, with Yeang’s associates, and the development included three major parks.

social sustainability
- The design takes the model of a geographical area of a city, with its inherent systems, zoning and social infrastructural elements into skyscraper buildings.
- The skyscraper and its retail and commercial base is seen as a microcosm of the city, containing within itself the inherent elements of a city block – parks, shops, entertainment centers, community facilities and housing, etc. The city in the sky concept provides for:
  - Opportunities for local employment through mixture of use both on ground and upper levels.
  - Healthy mix of residents within the same building. Through vertical zoning, residential types are grouped according to accommodation preferences (single units, family units, holiday apartments, etc.)
  - Close proximity to basic amenities such as the local grocery store, postal box, chemist, etc. These are all located within the ground development and within the lower levels.
  - A healthy landsapped environment with spatial progression of public open spaces (parks) on the sky to semi-private leisure courts to private open spaces (balconies).

b. maximisation
- The towers make the most of a westerly aspect to catch the winter sun. The variety of the sizes of the main units are also maximised. The minimal wind and rainfall capture the sun, creating a series of light wells to brighten the service areas in the apartments. The wings of the building allow cool breezes in the summer to enter the vertical atrium where shading it from the winter wind.

c. users
- Variety of units from different ages, numbers, sizes, types and family sizes are accommodated by the provision of a variety of accommodation types: studio apartments, one bedroom apartments and penthouses.
The singular difference here, contrasted with the Bishopsgate project, is the design of regular floor levels instead of the squalling ramped solution. Similarly, the apartment town plans have been rationalized into a rectilinear form, with winter gardens or balconies, similar to the Bishopsgate principle.

What is in evidence here, is the accomplished virtuosity of Yeang’s form-giving process, and the essential simplicity that results from this discipline. The Eco-Towers are a genuine reflection of Yeang’s evolving ecological architecture, which incorporates and develops its own aesthetic - largely that of an elevated landscape, and a visible social-awareness. Providing that the buildings are built with a matching standard of constructional quality and materiality, the Eco-Towers are set to achieve landmark status, within London’s regeneration.

<table>
<thead>
<tr>
<th>Ecosystem hierarchy</th>
<th>Site data requirements</th>
<th>Design strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ecologically mature</td>
<td>Complete ecosystem analysis and mapping</td>
<td>Preserve, conserve, develop only on non-white areas</td>
</tr>
<tr>
<td>Artificial</td>
<td>Partial ecosystem analysis and mapping</td>
<td>Increase biodiversity, develop on low impact areas</td>
</tr>
<tr>
<td>Natural</td>
<td>Partial ecosystem analysis and mapping</td>
<td>Increase biodiversity, develop in areas of non-production potential, rehabilitate ecosystems</td>
</tr>
<tr>
<td>Vegetation</td>
<td>Mapping of existing ecosystems components (eg. hydrology, remnant trees etc.)</td>
<td>Increase biodiversity and organic mass, rehabilitate ecosystems</td>
</tr>
</tbody>
</table>

[Diagram of Eco-Tower 1]

6. Use
The developments will incorporate housing, retail, leisure and commercial facilities and complement the retail levels and up the towers. The basis of housing in these areas will be employment, retail and leisure with community facilities to provide a safe and healthy environment.

b. Open space requirements / outdoor space
The design works to be made for elevations on the ground up to the sky, with terraces such as an entire sky-filling light well and decks for every flat and shared social areas and tennis courts, open spaces and sky paths within groups of buildings. The form of sky courts and communal paths the envelope of the towers is designed as a small garden.

c. Relationship to immediate context
The relationship to the immediate context is a key component in the design proposal, and the proposal here includes a high-rise building over the proposed railway station and direct connections onto the master plan and into the small areas.

d. Environmental sustainability
The approach to environmental sustainability here is a hybrid approach, in that it looks at both the efficiency of the systems and their impact on the environment. It is fundamental that ecological design not only considers the following aspects of a building:

- Its material independence, consisting of the designed system's relation to its external environment and ecosystems;
- Its internal independence, being the designed system's internal relations, activities and operations;
- Its external dependence on energy, being the designed system's supply of energy and material;
- Its internal material dependence on energy, being the designed system's output of energy and material.

The site is essentially a developed area with little of its original landscape, flora and fauna remaining.

7. Design strategy
The design strategy is to fit the local biodiversity and historic make by re-integrating the site as a whole to rehabilitate the site’s ecosystem. This is achieved by our provision of a park over the land and the adoption of a system of traditional planting up the towers (see "vertical landscaping")
ecological interactions in the recovery of the designed systems

- Input used in site rehabilitation, recolonisation by species, site recovery
- Input used in recovery processes
- Input used in preparation for recycling, reuse, reconstruction, and/or disposal, and safe discharge into the environment
- Input used in removal and demolition
- Input used in operation of built systems, maintenance, ecosystem protection measures, system modifications, etc
- Input used in construction and site modification
- Input used in distribution, storage, transport to site
- Input used in the production of the building elements and components (including extraction, preparation, manufacturing processes, etc)

inputs in the production phase

inputs in the construction phase

inputs in the operation phase

inputs in the recovery phase

overall embodied energy and embodied CO₂ for various building types

<table>
<thead>
<tr>
<th>Building Type</th>
<th>Embodied Energy Delivered GJ/m²</th>
<th>Embodied Energy Primary GJ/m²</th>
<th>Embodied CO₂ kg CO₂/m²</th>
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City of London

Site plan

Context plan 1: 7,500

Retail plan

drawn by HTA Architects
mixed mode concept

The diagram illustrates three modes of operational systems:

- productive mode (full)
- mixed mode
- passive mode

The productive mode represents the highest level of energy consumption, while the passive mode represents the lowest. The mixed mode is a combination of the two, allowing for flexibility in energy use. The productive mode is further divided into full and partial subcategories.

### Types of modes of operational systems

- **Productive mode** (full)
- **Mixed mode**
- **Passive mode**
- **Productive mode** (partial)

### Comfort ranges of different modes

The comfort ranges vary depending on the mode of operation, with mixed mode offering a midpoint between productive and passive.

### Passive low-energy responses

The design principles include optimizing solar gain and shading, utilizing passive systems like natural ventilation and shading devices. The building's orientation, landscaping, and vegetation play a crucial role in reducing energy consumption.

- **Building configuration**
  - The building is configured with two blocks, one with a central landscaped core.
- **Building orientation**
  - The building is designed to maximize solar gain and reduce thermal load.
- **Landscaping and vegetation**
  - Vegetation and landscaping are integrated into the design to enhance energy efficiency.

In summary, the design philosophy emphasizes sustainability, energy efficiency, and a harmonious relationship with the environment.
project teams + collaborators
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