Integrated Design

Stephen Harris
Jesse Mainwaring

Introduction

Integrated Design broadly describes a process that fundamentally engages the multiple systems of which architecture finds itself a part and of which architecture is comprised. These range from tectonic and mechanical systems to social and economic systems to the design team itself. For the purposes of this study we will look at Integrated Design as a process that facilitates the coordination of different disciplines (or methods of inquiry) and the interaction of various building systems in a holistic and team-based manner, with the goal of designing more energy-efficient and sustainable buildings. This process, however, is mutable and should be modified to include whatever necessary parameters define the specific design problem(s). What we describe, then, is a general approach that is not exhaustive in scope, but rather emblematic of the potentials inherent within Integrated Design.

A Systemic Approach at Varying Scales

Central to Integrated Design is an understanding of the inherently complex and variable network of systems of which any given project finds itself a part. As each building is a component in a larger system, it is important to understand the implications of intervention both in order to operate in concert with existing networks and to take advantage of opportunities that they can offer. Cultural heritage, local economies, common building practices, existing and proposed infrastructures, and so forth operate within the larger environmental context at various scales, from local to regional to global. Much of this information can be understood quantitatively and much cannot. It is easy to measure solar radiation, for instance, but quite difficult to grasp the nuances of a dynamic social system. An Integrated Design approach strives to synthesize...
both quantitative and qualitative understandings of manmade and natural contexts. This is key to develop an architecture that is sensitive to both and allows each to act sensitively toward the other.

Integrated Design looks at the internal structures of a building in a similar way. Gone is the concept that various building systems can be conceived independently, or that they operate in isolation. Instead, each building is conceived as one system, comprised of multiple and interrelated sub-systems that work together to limit energy expenditure as they provide comfortable and meaningful shelter. The understanding of mechanical systems changes dramatically as the standard conceptual dominance of their isolated-component status is replaced by performance requirements alone. Instead of a list of various ‘necessary’ mechanical systems, Integrated Design sees ventilation, thermal comfort, and lighting (and others) as parameters that are affected and moderated by carefully designed interaction between various building components and building form. Thus, a conventional HVAC system may disappear as its roles are variously performed by collaboration between the building envelope, structural system, and the sun, as can be seen in the San Francisco Federal Building case study below.

A key goal of Integrated Design is to optimize the entire building system, rather than a single sub-system. To do so, it is necessary to understand the potential performance overlaps that exist among building systems, components, and form, and their relationship to climate. Figure 01 shows a matrix of key parameters, broken down into two categories (Design and Energy), that describes the interaction of various possible building elements. While this matrix is not conclusive, it begins to develop an understanding of the influence one sub-system has on another,

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Figure 02: Interaction of design and energy parameters. (Adapted from Santamouris)

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Figure 02: Interaction of design and energy parameters. (Adapted from Santamouris)
and can be helpful in developing a strategy for an Integrated Design. What it does not show, however, is the appropriateness of a strategy within its cultural and environmental context. It is through the application of a contextual understanding to an understanding of potential building strategies that a truly integrated design becomes possible.

**Privilege the Passive**

While Integrated Design has broad implications, we are primarily concerned with its potential for energy efficiency. Instrumental in achieving such goals is a privileging of passive over active strategies for building comfort. Building form, fabric, orientation, and envelope all have inherent potentials that can be evaluated to passively maximize building efficiency. The building form has wide-ranging consequences that affect everything from the ability to use natural daylighting to thermal gain. The building fabric is, among other things, critical in determining thermal mass and can allow parts of the building to act as heat sinks. The building envelope can facilitate various energy exchanges and, for example, can allow the building to make use of the sun for thermal comfort and daylighting, and prevailing winds for ventilation. Building orientation is once again a key determinant, with consequences covering ventilation, thermal comfort, and lighting as well. Despite the high potential for energy savings within each of these components, a careful understanding and coordination of all is generally necessary to maximize the performance of the entire building.

**Develop Collaborative Teams**

Integrated solutions will not come without a change to the design process itself, and that begins with the design team. Integrated Design reorients the design process away from the myth of the singular architect and toward collaborative teams comprised of various experts, flexibly organized toward the specific design problem. Based on the understanding that professional integration precedes technical integration, collaborative teams allow the design process to confront a variety of aesthetic, organizational, and technical issues from its onset. These teams are variously composed of architects, engineers, contractors, landscape architects, the client, the community, and so forth. With input from these sources during all design phases, issues pertaining to climate, performance, cost, constructability, inhabitability, culture, and so forth can be expertly considered and integrated into the final design.

For example, the Austin City Hall case study described below involved a design team composed of both generalists and specialists, including: the design architect, the architect of record, structural engineers, civil engineers, mechanical systems engineers, parking consultants, landscape architects, signage/graphic designers, lighting designers, solar energy consultants, waterscape designers, and security consultants. Additionally, it should be noted that input from the community and the city government (in this case, the client) were also integral to the process.

**Strategies**

In general, an Integrated Design process can be conceived of as a feedback cycle with definable steps that occur in a flexible and non-linear structure. While the exact structure, types of information, and team members will vary with the specifics of a given design problem, it is still possible to outline a strategy by which an integrated architecture can arise (See Figure 02). To begin with there are four general stages that vary between information-gathering and processing, and design.

**Define the problem(s) and boundary conditions:**
The first stage of an integrated process involves defining the specific design problem and the parameters that will bear influence upon it. This is primarily a phase of information-gathering that will look to building program, site, ecology, climate, infrastructure, cost, and any other important data in order to coordinate an appropriate design team and gain an understanding of the specific intricacies involved within the project.

**Develop strategies and options:**
Following initial analysis, the design team will apply its knowledge and expertise toward the development of design strategies including thermal comfort, lighting, ventilation, construction and so forth. This phase is similar to the Concept and Schematic Design phases of a conventional design process, differing mainly in its inclusion of team members and data that would otherwise not be present.

**Apply tools and knowledge; Evaluate:**
Once potential strategies and
options are developed, they need to be tested against the information gathered at the onset of the design process. This is generally accomplished through the application of various metrics in order to evaluate a given option’s potential for success. These include: Energy modeling simulations using software such as Ecotect, eQUEST and others in order to estimate the performance of an option; LEED and other certification programs which offer guidelines to evaluate an option based on a given list of criteria; conventional calculations; user surveys; etc.

Adjust strategy based on metrics: After the strategy has been evaluated, it will be modified as necessary in response to the data collected. Following any adjustment, each iteration should oscillate between evaluation and improvement until the design meets the performance requirements established at the onset of the design process. This phase is similar to the Design Development phase of a conventional design process.

Two caveats are worth mentioning. First, it should be stressed that despite the linearity of this description, the design process should be conceived of as flexible. It may become evident following computer analysis, for example, that additional boundary conditions bear more weight than originally expected and may require a redefinition of original assumptions. Thus, at each moment of evaluation, the design process will develop its own trajectory, referring to and adjusting whatever phases necessary in order to integrate the most appropriate parameters into the design/building strategy. Secondly, a phase of analysis following construction should be added to this list, in order to evaluate the performance of the building in reality. This will help not only to ensure that the building performs at its highest potential efficiency, but will also help to establish a body of data and literature that will prove useful for future projects.

Case Studies

Each of the following projects was developed through an Integrated Design process. Taken together, they stress the variability of parameters, the nuance of process, and the uniqueness of result that is inherent to Integrated Design.

Each is a high-performance building developed through careful integration of various strategies, united in their goal of developing a highly efficient and meaningful architecture that contributes to a sustainable and optimistic vision of the present and future. These projects should not be taken as a complete or exhaustive catalogue of possible outcomes or strategies related to Integrated Design, but rather as a loose collection of examples that illustrate our points on the topic.
Austin City Hall

Client: City of Austin
Program: City Hall Building – offices and facilities for 350 people, mayor & city manager offices, council chambers, parking
Location: Downtown Austin, TX – mid-rise urban context

Climate: hot and humid
Heating Degree Days: 916
Cooling Degree Days: 1652
(18 degrees Celsius base)
Avg. Annual Precip.: 85.47 cm

Design Parameters

In its project brief the City of Austin requested that the new city hall building engage the idea of sustainability in several ways that can broadly be distilled into two categories: social- and performance-based issues. In terms of performance, the City of Austin was interested in a building that was energy-efficient in its construction and operation, while utilizing local materials that had a minimized carbon footprint. The project was also to be low-maintenance and built to last, indicating the city’s savvy with regard to life-cycle analysis. The city’s primary concern about the social aspect of sustainability was that the citizens it represented embraced it, again hopeful that would ensure a long life for the building. This idea provided the context for the quality of life parameters the building addresses. Not least of these parameters was to design a building that engages the city through publicly accessible indoor and outdoor...
spaces that promote activities at all hours. Secondly, the building was to promote public participation in government.

**Design Process**

The idea of public participation began before the project got through the design phase, however. In the planning of Austin City Hall, Antoine Predock, the lead architect, also local architects, Cotera + Reed, engineering and interiors consultants, landscape architects, and water consultants. In addition to these ‘professionals,’ however, per stipulations set by the City of Austin upon his commission, Predock also took public feedback from the citizens of Austin. This public input came not only from public meetings with the design team, but also from a much more accessible and democratic process: a downtown storefront displaying the potential design, and soliciting anonymous suggestions via comment cards. Though the process was long and cumbersome, prompting Predock to describe it as “terminally democratic,” it resulted in a building that the notoriously outspoken citizens of Austin felt represented their value of transparency and openness in government.⁵

**Strategies**

As a response to the climate of Austin and the given design parameters, the design team chose to employ several nested strategies that could solve design problems at multiple scales. The building is heated when necessary with a gas boiler, but its cooling system uses a heat exchanger to tap into a district cooling network that provides cold water to a large part of the downtown area. Through this cooling system (the dominant indoor temperature control system required by the Austin climate) Austin City Hall nests itself into an urban-scale strategy for energy efficiency. The building runs an efficient closed-loop cooling system, while the most densely populated part of the city reduced its peak energy demands by chilling the water for the district cooling grid at night, when demands are much lower. The building also generates some of its own power, however, by means of a scrim-like photovoltaic array that steps down the south façade, terminating in the form of the canopy of a public seating area. This single element harvests renewable energy for the building and provides shade to a seating area on a large public plaza, addressing
both the performative and social goals of client. The energy concept is furthered by the use of occupancy sensors for the interior lighting and demand-based air-conditioning and fans, meaning that the building only uses energy when it is necessary. Natural light is used extensively in the building interior, further cutting down on its energy consumption. Clerestory windows in the offices allow useable natural light to penetrate deeper into the spaces, while reflective surfaces, such as the copper cladding, bounce light around the building’s interior. What energy the City Hall does purchase from Austin Energy is provided through the ‘green choice’ energy plan that provides only renewable energy.

As the building terraces down to the south, it employs green roofs as well. These areas as well as the landscaping at ground level are planted with native plants. Not only does this system reduce the building’s energy load and act against the urban heat island effect, but it has also been registered with the National Wildlife Federation as a certified wildlife habitat for birds and butterflies. All of the landscaping at Austin City Hall is watered using the recycled condensation from the cooling system. Additionally, when the below-grade parking structure was being dug, the workers found a small spring. The design was adapted to use this water in a feature that provides evaporative cooling to the transitional space between the parking garage and the building.

Evaluation / Conclusion

One of the main evaluation tools used in the design of Austin City Hall was the rubric provided by LEED. At the outset, the design team’s goal was to produce a building that would achieve LEED silver status. While using LEED as a primary metric is debatable in terms of quantitative evaluation, it is a commonly used and valid tool. Embedded within the LEED plan are requirements for both energy-efficiency and quality of life, two values of equal importance to the City of Austin. When the building was inspected for LEED certification it surpassed its goal of silver, achieving LEED gold. This was likely due to its Integrated Design process, and the efficiency of the building as a whole that resulted from it. The building was also recognized by the organization Green Roofs for Healthy Cities for its multi-faceted approach to urban landscaping.

Figure 07: Landscaping encourages public use of Austin City Hall.
Phoenix Central Library

**Client:** City of Phoenix  
**Program:** Central Library – flagship location for the Phoenix library system, with a grand reading room, rare books collection, auditorium, technology and information center, and children’s library.  
**Location:** Downtown Phoenix – urban context

**Climate:** hot and dry  
Heating Degree Days: 571  
Cooling Degree Days: 2424  
(18 degrees Celsius base)  
Avg. Annual Precip.: 21.06 cm

**Design Parameters**

The program of a library, and particularly a facility for a rare books collection, required precise and specific interior climate conditions for this project. Given the harsh climate of Phoenix, this was the main boundary condition of the project. In addition, the project was publicly funded, which resulted in a very tight budget: $100 per square foot. Energy efficiency and passive systems were, of course, privileged as both a statement about sustainability and a cost-cutting strategy. Will Bruder, the primary architect, was already known at the time for his belief in the way one should build in the desert climate of the American Southwest, but this project was much larger than any he had built at the time.

**Design Process**

…we started a whole series of analyses prior to and conceptual thinking about an idea. With a group
of very, very fine engineers (and that was the Arup group in Los Angeles, California), we sat down with them while all these other meetings were going on in one area, and we said: 'OK, guys, let’s talk in the abstract. How can this be the best building ever built in our time? What does it mean in this desert place? How do we have to conceive it? What becomes the materiality? What is the right attitude about exposures of buildings and the things we have to think about and do? What’s that all about?’ – Will Bruder, on the design process.

Clearly, the design process for this project was highly integrative from the very beginning. The building was immediately conceived of as a singular problem to which all of the various consultants brought their expertise. Bruder envisioned that the solution to this problem would be multiple systems working together. Even before physical form was given to anything, the design team began trying to identify the strengths and weaknesses of various systems, ranging from air quality to structure, in order to determine the possibilities for their combination.

Strategies

As a relatively cheap and effective structural system, precast concrete was considered early in the design process, but the thermal mass of this material was equally important. With the large diurnal swings experienced by Phoenix, the design team concluded that thermal mass could temper the interior climate of the library by soaking up heat during the day and releasing it to the desert sky overnight. Each day, the system would reset itself. This decision generated massive concrete walls on the east and west facades, with the north and south providing the only available natural light. All of the buildings services and non-essential functions, such as vertical circulation, restrooms, and maintenance facilities, were moved out of the interior of the building and into the massive east and west walls. As a result, the walls thickened and grew into what Bruder referred to as “saddlebags,” providing space for all of these functions, as well as the lateral bracing for the structure. This also reduced the building’s energy usage, as the saddlebags are not temperature-controlled through the building’s mechanical systems.

The north and south facades of the library are mostly glazed to allow natural light into the interior spaces, but in order to cut down on solar heat gain, each has a shading device specific to its orientation. The south-facing glazing is shaded by a system of horizontal louvers modeled off an existing system on a research building located at Niagara Falls. These louvers are computer-controlled, tracking the sun’s path each day to allow only indirect natural light into the library. The north façade takes a much less technical but no less effective approach, using a stationary shading device referred to by Bruder as “shade sails.” The name is apt, as the material from which they are constructed is adapted from sailboat sail technology. These stationary shading devices run vertically along the façade, but angle to alternating sides to shade the glazing behind them.

The efficient gas-powered mechanical systems of the building are all integrated into and regulated.
by a central building services management system that measures the required heating, cooling, and ventilation, and responds accordingly. These mechanical services are all zoned, to allow them to be used only where needed, and the building is only conditioned during business hours, allowing the diurnal swing to cool the building at night. The temperature in the Great Reading Room on the top floor is regulated only in the lower section of the tall space. The central building services management system only measures and manages air temperature in the occupied portion of the space (the first 9' up from the floor), and the rest is allowed to get hotter than would be comfortable. This temperature stratification was designed to reduce energy consumption by not conditioning space that would not be occupied.

**Evaluation**

The design team simulated their proposed strategies before accepting the design as final, using calculations to determine the systems’ effectiveness and even mocking-up a piece of the structure to test it. This evaluation process proved to be extremely influential on the final design. The thermal simulations done by the engineers at Arup, determined that the 12-inch thick concrete walls that comprised the east and west structural walls required no additional insulation as they have enough thermal mass and are continually shaded by the flanking saddlebags. Lighting and thermal analysis was done on the north and south facades to determine the effectiveness of their respective shading devices, which revealed that the north façade received on average only three to four hours of direct sun per day due to the shade sails. These calculations also showed that whereas the original plan for south façade was to sandwich its louvers between glazing, the outer layer was not needed. In addition, these simulations revealed the appropriate percentage of perforation for the copper cladding that covered the saddlebags. A 10 percent perforation with 90 percent copper provided best balance of shade and natural ventilation to the unconditioned space behind this scrim.

**Conclusion**

Once the building was completed, an independent group evaluated its performance, revealing an annual energy usage of 225 kilowatt-hours per square-meter. This figure corresponds to the average annual energy usage for educational buildings in 1999, which had far fewer hours of operation and wider tolerances for interior temperature and humidity. They also measured the temperature differences between the core of the 12-inch thick west wall and the average interior and exterior temperatures over the course of the day and year. Their measurements show that the average temperature difference between the core of the wall and the interior fluctuates from 0 to + or - 3-4 degrees Fahrenheit over
the course of the year. This seems to indicate that there is some heat passing through the wall and into the interior of the library, but it is doubtful that adding insulation, as had been considered during the design phase, would have improved the wall’s effectiveness, because of the resulting diminished capacity for nighttime cooling. The same group also compared the average air temperature inside the occupiable space of the saddlebags to that of the outside air, determining that the air temperature inside the saddlebags is about 10 degrees Fahrenheit cooler. This effect is due to the perforated copper scrim on the exterior, which provides shading and ventilation. The final measurements taken addressed the performance of the temperature stratification of the Great Reading Room. The data indicate that while there is great stratification in the summer, there is little or none in the winter. Over the course of the data set, the highest recorded temperature was 92.5 degrees at the top of the room (July 22, 2005, 7:20pm), while the occupiable space below remained well within the comfort level during operating hours. The conclusion posited was that the building performance could be improved with increased roof insulation.

Overall, the performance was quite good for a building with such specific interior climate requirements, given that it was completed in 1995. In fact, the building it replaced used approximately twice the energy of the new Central Library. Of the 225 kilowatt-hours per square-meter used by the library, 84.5 were generated through the use of natural gas. This drastically reduced the building’s carbon footprint as gas generally releases about half the amount of carbon-dioxide during production compared to coal-based electricity.

Figure 12: Inside the saddlebag.
San Francisco Federal Building

Client: U.S. General Service Administration

Program: Office building – general office space for roughly 1400-1500 employees of federal agencies

Location: Downtown San Francisco – urban context

Climate: temperate
Heating Degree Days: 1442
Cooling Degree Days: 61
(18 degrees Celsius base)
Avg. Annual Precip.: 56.59 cm

Design Parameters

As another public project, this building was also designed on an extremely tight budget. Another major issue was flexibility of the interior required by the client. Since the program was general office space for employees of various federal agencies, the space had to be flexible enough to adapt to whatever agency moved into it. Generic floor plans and open flexible space were necessary to accommodate the needs of the client. The U.S. General Service Administration set a goal for the project to use less than 173.5 kilowatt hours per square meter per year. The client also requested as part of the project brief that the building be publicly accessible and pedestrian-friendly, allowing a sense of public ownership and responsibility for this publicly-funded project. A major boundary condition posed by the site of this project was the axis of the street grid of downtown San Francisco. The site ran roughly 45 degrees off of the east/west axis, meaning that far too much solar radiation was possible on the northwest façade.
Design Process

The architecture firm involved, Morphosis, prides themselves on work that, while not seeking to be labeled 'sustainable,' is based in high-performance systems. For this project the systems involved had to be integrated in such a way as to provide an interior condition appropriate to a generic office tower, while keeping costs low. Taking this workable interior environment as a starting point, the design team sought ways to use the temperate San Francisco climate to their advantage. The team worked through the systems acting in the building by diagramming their interactions and the possible outcomes, stripping out anything they could to achieve as concise and effective a system as possible. The design process of this project was special in that included in the team were six artists who were commissioned to create murals and installation art integrated into the new building.

Strategies

The temperate climate of San Francisco played an important role in the energy-efficiency of the Federal Building, and while the rotated street grid of the site provided too much potential for solar heat gain on the northwest façade, it also happened to align the site with the dominant wind patterns of the area. This was taken as a jumping off point, and cross-ventilation became integral to the energy concept. Cross-ventilation requires certain formal moves, however, so the tower was made very shallow, allowing fresh air to pass through each floor. This floor plate also allowed for natural light to penetrate the space, which meant that this light had to be allowed into the interior to varying degrees depending on the orientation of the façade. To deal with this issue, the design team treated each façade differently, with louvers and a mutable perforated metal skin allowing mostly indirect light into the workspaces. Additionally, all of the work areas are positioned around the perimeter of each floor plate, to allow maximum access to natural light and fresh air via operable windows. The stainless steel skin, perforated with a 58 percent openness factor, is comprised of individual panels that are controlled by the building’s central computer system to adjust to the daily and seasonal climate changes of the site. The curtain wall behind this skin also contains glazing units that are computer-controlled to adjust to the ventilation needs of the office space. This flexible skin and glazing system deliver natural light to 90 percent of the available work space and natural ventilation to 70 percent, allowing this project to become the first US office tower to forgo air conditioning in favor of natural ventilation. The bottom of the building spreads out to occupy more of the site and provide public access, and the bottom 5 floors, that is to say those below the tower, are fully air conditioned.

Another component to the energy

Figure 14: Work areas are placed toward the outside walls to allow for daylighting and ventilation.
concept of this building is the use of thermal mass and nighttime cooling. The concrete floor plates have a sinusoidal shape on the underside, increasing thermal mass potential ceiling the ceiling of the workspaces below. Because of this the standard drop-ceiling has been eliminated in favor of a raised floor. This not only exposes the thermal mass on the ceiling, but also allows more efficient access to conduits and more flexible arrangement of workspace. As with the Phoenix Central Library, another project that uses thermal mass, the San Francisco Federal Building is only conditioned during business hours. At night the windows are opened, allowing night breezes to cross-ventilate each floor and recharge the thermal mass with cool air for the next day. This not only cools the concrete slabs, but also flushes out the warm, stale air in the offices.

**Evaluation**

Energy, thermal, and lighting simulations were extremely important in this project because its success was based so heavily on its advanced energy concept. This modeling showed that the building could surpass the client’s energy consumption goal by more than 50 percent, using just 78.9 kilowatt hours per square meter annually. The evaluations also showed that the lighting concept for the tower was extremely effective, allowing 85 percent of the total available workspace to lit naturally, and decreasing the energy used for lighting by 26 percent. The natural lighting is supplemented with automated powered lights. Because of the building’s orientation, solar heat gain was inevitable, and the thermal simulations run allowed the design team to turn this fact into an asset, by eliminating the need for heating the tower altogether. Thermal modeling showed that even on the coldest day of winter, the building would still generate excess heat. It also showed that the nighttime cooling and thermal mass were sufficient to cool the building for the next day’s use, when combined with shading and ventilation during the daytime hours. The models showed that the interior temperature would exceed the ASHRAE standard of 72 degrees Fahrenheit, but would only exceed 79-80 degrees for about 8 hours per year. The design team took this as an acceptable condition, citing examples in the northern states of people missing work more regularly than that on account of sleet, snow, and cold weather.

**Conclusion**

An independent group tested the
San Francisco Federal Building’s energy concept using actual temperature data and an advanced computer model to simulate the building’s performance.\textsuperscript{18} While this study was not completely ‘real,’ and is perhaps less meaningful than that of the Phoenix Central Library, it still provides a benchmark that falls somewhere between ‘completely simulated’ and ‘completely real.’ The test examined the building’s performance following a stretch of three of the hottest days of the year, which fell in the first week of July in 2006. During this period, the outdoor temperature peaked at 95 degrees Fahrenheit at 3:00 pm on the second of the three days. After the three extremely hot days, when the slabs would presumably be most likely to retain their heat overnight and into the next day, the interior climate was still shown to maintain a temperature within the comfort zone for the given hours of occupation. This was due to the effect of nighttime cooling and cross-ventilation, as well as the cooling effect of cross-ventilation and shading during the daytime hours.

Figure 17: Inside and outside temperature fluctuations over the course of a week in July. (Lerum)

Figure 18: A sinusoidal exposed concrete slab forms the ceiling of the workspaces on each level.
Libyan School System

**Client:** National Consulting Bureau of Libya  
**Program:** Design concept for a school - system with potential to be adapted other programs as necessary  
**Location:** Two examined: Tripoli and Desert

**Climate** (Tripoli): hot and humid  
Average temperatures range from 30 degrees Celsius (summer) to 8 degrees (winter), with an average annual precipitation of 380 mm.

**Climate** (Desert): hot and dry  
Average summer temperatures of 30 degrees Celsius drop to mean minimum temperatures of -5 degrees in the winter. Daytime winter temperatures remain between 15 and 20 degrees, however, and, being a desert region, there is very little precipitation.

Design Parameters

This project was intended as a design concept, and has not yet been realized. As such, its main design parameters relate to providing a flexible system of building for the two main climatic regions of Libya: the hot, humid areas of which Tripoli is representative, and the hot, dry areas of the desert. The flexibility and adaptability of the design is therefore very important to the final product, as is the energy and thermal concept.

Design Process

The design team involved in this project was large and included many consultants, with the primary architects involved being Herzog + Partner in combination with Werner Lang. To begin the process, the design team did extensive research into Libya and its, history, climate, architectural heritage, school systems and buildings, and...
available building resources. This information was then processed and distilled and clarified with the client before any planning took place. Five main design problems were identified: program, modularity and flexibility, structure, façade, and energy concept. The design team established various options for each of these systems and tested them against each other in order to establish a basic scheme.

**Strategies**

The design team chose a system of prefabricated modular structural systems because of its adaptability to various programs, sizes, and locations. From that point, the ideas of thermal mass in precast concrete, natural ventilation, the stack effect, and shading of the building and ground became important. With the blocks of interior space organized around shaded courtyards, the modularity of the system began to take shape.

The solar chimneys rising through the interior spaces serve as a ventilation system creating a stack effect to draw hot air out the top of the buildings and cool air in from below. The massive canopies penetrated by these chimneys, together with vegetation, were used to completely shade the buildings and courtyard. Passive cooling of the classrooms in the hot climate was also achieved though the intake of tempered air that passed under the shaded earth below the building. For more moderate conditions, the interiors can be cooled passively through cross-ventilation. The ventilation system was designed to allow hot air to be pulled up and out of the classrooms through thermal buoyancy, pulling cooler air in to fill its place. For the hot and dry desert climate type, evaporative cooling was recommended for the courtyard area. Cooling loads, of course, vary depending on program, and a computer room would require considerable more cooling than might be possible by passive means alone. Because of this, various mechanical cooling systems were compared as well, and considered as a piece to the thermal comfort puzzle.

The interior spaces were designed to be lit using indirect daylight allowed in but modulated by shading devices. The room depth was specifically calculated to allow for maximum utility based on both flexibility of classroom space and usable natural daylighting. Several different façade-mounted shading devices were compared, and because of the flexible nature of the design concept, any of them is possible. Options ranged from adjustable to fixed and from louvers to vegetation.

**Evaluation / Conclusion**

To examine the interior climate conditions further, two different comfort standards were chosen because of the difference in humidity between Tripoli and the desert. These were then compared to the actual outdoor weather conditions for the year to determine what sort of interior conditioning was necessary. Energy calculations were run based on the established design concept, in order to determine what the energy consumption would be in various conditions of climate and use. Embedded in those calculations were four different air conditioning systems: a standard passive system, cooling of ventilation air using
water evaporation, conditioning of ventilation air using sorption technique, and solar cooling using absorption chilling. Various usage patterns were evaluated, ranging from only maintaining the interior climate during the normal school day and excluding the summer months to an extended period of use into the evenings and summer months. The most efficient model restricted use to a standard school year.21

Multiple shading systems were also tested: no shading, fixed shading projecting 100 cm, and fixed shading projecting 150 cm, with the 150 cm shading performing the best. A daylight factor (the percentage of available outside light that makes it inside) of 6 percent was achieved at the façade, and a daylight factor of 2 percent was still achieved 6.5 meters into the room. With no shading present, the daylight factor at the façade was 11 percent, more than double the recommended 5 percent. With a 100 cm fixed shading structure, the daylight factor was lower but still too high at the façade, reaching 8 percent. The 150 cm fixed structure reduced the daylight factor enough to achieve desirable results near the façade, while maintaining the same results as the other two options at a depth of 6.5 meters into the room.22

Since this design concept has not been constructed, it is difficult to judge its actual performance, but its test results are extremely impressive. Despite being unbuilt, it was nominated for an IBS award in 2008. As a design concept, it is very well documented and its report shows evidence of an extensive Integrated Design process. One can easily see in the elegant and high-performing final product the benefits of working in a larger and multi-faceted design team.

Final Thoughts

As can be seen in the previous case studies, Integrated Design is broad and variable. Team members vary from project to project as do design parameters, data, and strategies. What ties these projects together is not a focused similarity in climate, form, or approach, but rather a decision to engage in a process that integrates various experts and building strategies to develop an energy-efficient and sustainable building.

As with any change of convention, Integrated Design yields incremental benefit. The Phoenix Central Library, while impressive at the time of its construction pales when compared to newer buildings such as the San Francisco Federal Building. This is not because of a failure on behalf of the library’s design team, but is rather evidence of the learning curve
involved. As professionals adapt to an increasingly integrated process they are able to achieve increasingly better results. At the same time, metrics by which a design team is able to evaluate performance are continually developing. With each new measure of quantitative and qualitative data, a design team is able to more accurately understand the overlaps between building performance and design strategies. Through a combination of good tools and experienced, integrated teams, continual progress can be made toward a more energy-efficient and sustainable landscape.

**Figures**

Figure 01: Antoine Predock.
Figure 02: Santamouris, p. 316.
Figure 03: Harris and Mainwaring.
Figure 04: American Hydrotech.
Figure 05: Antoine Predock.
Figure 06: Antoine Predock.
Figure 07: City of Austin.
Figure 08: Ojeda.
Figure 09: Ojeda.
Figure 10: Lerum, p. 259.
Figure 11: Wigginton and Harris, p. 100.
Figure 12: Ojeda.
Figure 13: Morphosis, morphopedia.
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Figure 15: Morphosis, morphopedia.
Figure 16: Morphosis, morphopedia.
Figure 17: Lerum, p. 229.
Figure 18: Morphosis, morphopedia.
Figure 19: Herzog and Lang (10/03), p. 80.
Figure 20: Herzog and Lang (10/03), p. 18.
Figure 21: Herzog and Lang (10/03), p. 42.
Figure 22: Herzog and Lang (10/03), p. 15-16.
Figure 23: Herzog and Lang (10/03), p. 50.
Figure 24: Herzog and Lang (10/03), p. 56.

**Notes**

3. Connolly, p. 25.
5. Schwartz and Coppola.
6. Lerum, p. 239.
7. Lerum, p. 255.
8. Lerum, p. 255.
16. Lerum, p. 222.
17. `The Federal Government was concerned about this to an extent, but they also have to close buildings in Minnesota because of snow accumulation` - Tim Christ, project manager - Lerum, p. 222.
19. The primary source for almost all of the information contained within this case study is an unpublished report co-authored by Thomas Herzog and Werner Lang (10/03), p. 6.

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