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Sustainability Impact of Tall Buildings: Thinking Outside the Box!

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Abstract

Applying the criteria regularly used in sustainability assessment of "ordinary" buildings leads to the observation that tall buildings are "not sustainable." But nothing is ordinary about tall buildings and such an evaluation is not appropriate. While tall buildings may not measure up to the same sustainability standards applied to not-tall buildings, they do indeed have a significant sustainability impact if assessed within their appropriate context. This paper promotes the idea that in evaluating "sustainability" of tall buildings, we must look at their sustainability impact beyond their physical boundaries and within the urban context.

Keywords: Tall, Building, Sustainability, Impact, Urban, Density

1. Introduction

The concept of sustainability applied to buildings means different things to different people. Some have a limited view of sustainable buildings being energy efficient. A more complete view may consider high-performance buildings with reliance on renewable sources of energy as sustainable. Yet others may have an even more encompassing view.

Clearly, energy source and energy efficiency of buildings are critical parts of sustainable development. After all, buildings are significant consumers of energy. For example, it is commonly understood that more than 40% of total energy used in the United States is used for operating buildings. Therefore, conserving energy is not only a sensible obligation to protect our resources and the environment, it is also recognizing a strategic commodity. In the words of former U.S. President Obama, "… the nation that leads the clean energy economy will be the nation that leads the global economy."

While energy efficiency is a critical aspect of sustainable development, there is much more to the subject. Sustainability must be viewed in a comprehensive manner and should include ecological, social, and economic considerations of a particular building in its own *context*.

The criteria often used to assess building sustainability may include the following: judicious use of our natural resources; minimizing waste in production of building products; use of material with as low as possible embodied energy; use of local material to the extent possible; minimizing construction waste; an integrated and holistic approach to design of building systems from the structural system to mechanical, electrical, vertical transportation, and other building systems; and reliance on renewable energy sources as much as possible.

In addition, monitoring the buildings' actual performance in operation and how that performance is measured and evaluated are important considerations. On one hand, we can learn a lot about how accurate our design models and assumptions are. On the other hand, a lot can happen between the design stage and operation stage of a building with outcomes that may be different, even significantly different, from what was intended or designed.

2. Are Tall Buildings "Sustainable?"

Tall buildings require more structural material per unit floor area than shorter buildings. In the words of the late structural engineering genius Fazlur Rahman Khan, there is a premium to pay for height in tall buildings. The structural system of a tall building, in particular its lateral load resisting system, requires more structure and thus more material to provide the necessary stiffness to limit the building's lateral movement due to wind or seismic forces to within acceptable thresholds (Fig. 1).

Delivering material to high height during the construction of a tall building requires more effort and energy, making construction of tall buildings appear "less sustainable." Further, because of their nature, tall buildings require more energy for certain of their systems and services such as vertical transportation, pumping water as well as other Mechanical, Electrical, Plumbing and Fire Protect-

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Figure 1. Tall building subject to wind (Istanbul).



Figure 2. Blue Cross Blue Shield Building (Chicago).

ion (MEP/FP) systems. In fact, the initial embodied energy of tall buildings on a per floor area or per person rate may be in the range of about 150% or even higher than that of low-rise buildings.

Design of newer tall buildings benefits from the expertise of professionals at the forefront of their fields. Therefore, they encompass innovative and efficient systems that require less energy to operate. However, due to additional energy used by their numerous amenities, tall buildings end up consuming energy at a higher rate than other buildings.

The architecture of the modern tall building often comprises a considerable amount of glass. This characteristic leads to much higher glass to wall ratios than not-tall buildings. While glass is, rightly so, an integral part of today's tall building architecture, it is not the most efficient building insulation material! Despite considerable advances in glass technology, the insulation properties of glass still cannot compete with ordinary buildings insulation materials. Therefore, there may be a higher rate of heat loss or heat gain in a tall building, depending on the location, than not-tall buildings (Fig. 2).

Research (Du, 2017) that compared downtown high-rise versus suburban low-rise living in the Chicago area has shown that, "On a per floor area basis, downtown residential towers consumed 4.6% greater energy than the suburban low-rise residential buildings. On a per-person basis, the high-rise residents consumed 27% greater." Although the demographics and life style of those living in downtown high rises is often different from those living in the suburbs, nevertheless, the per capita energy consumption of those living in high rises is considerably high.

Finally, end of life or de-construction of a tall building will be a considerable challenge requiring more energy and produce much more waste than not-tall buildings. We design tall buildings as if they will forever remain fixtures on the face of the Earth. The fact is that at some point, and for various reasons, tall buildings may need to be de-constructed. The taller the building, the higher the adverse impact of de-construction of the building on the environment. This characteristic too, will adversely affect the "sustainability" of tall buildings.

Consequently, the answer to the question, "Are tall buildings sustainable?" is absolutely not, if we use the same criteria for tall buildings as we do for their shorter

counter-parts. But doing so would be wrong, anyway.

The measuring sticks regularly used for assessing sustainability of a building may be appropriate for an "ordinary" building. However, nothing is "ordinary" about tall buildings! Just as it would be inappropriate to compare the fuel consumption of a passenger car with that of a bus or a large truck, applying the criteria developed for sustainability assessment of ordinary buildings to tall buildings is wrong. Any such comparison would be unfair and inappropriate.

3. Urbanization and Growth of Tall Buildings

Recent years have witnessed an unprecedent growth in construction of tall buildings. According to statistics from the Council on Tall Buildings and Urban Habitat (CTBUH), there has been an average annual growth of 35.8% in buildings 200 meters or taller world-wide over the past 50 years. At this rate, 50 years from now, there will be over 3,600 buildings 200 meters and taller, in the world. And according to the same source, 41% of tall buildings today are residential as opposed to 35% in 1969. Simply put, more and more people migrate to live and/or work in urban areas each year.

Cities with tall buildings in their skylines are often viewed as successful, financially prosperous and forward-looking. Like magnets, they attract people and businesses to them at relatively high rates. Cities such as Singapore (Fig. 3), Shanghai, Kuala Lumpur, and New York have indeed become world centers for commerce. People move to these and other large cities for better career opportunities and for their preferred lifestyle.

A recent trend around the world is for younger double-income-no-children (DINC) couples to move to large cities to live near their place of work. Research has shown that even with today's technological advances, density increases productivity. One such report (Buchanan, 2008) states, "… doubling of employment density within a given area can lead to a 12.5% additional increase in output per worker in that area. For the service sector the figure is far higher at 22%." Other researchers (Willis, 1995) have long advocated the relationship between tall building development and their economic impact on the surrounding area.

According to the 2018 statistics from the Pew Research Center (Pew, 2018), there has been an overall increase in urban population in the United States of 16% since year 2000. According to the same source, the rate of migration of the age group 65 years and older to urban areas looking for a different life-style has increased by 26% over the same period. Some of these rates are higher in other countries, particularly in parts of Asia. For example, according to CTBUH statistics, over the last 50 years the rate of urbanization in China has grown from 17.4% to 60% and the number of Chinese buildings 200 meters or taller has gone up from 0% to 41.7% of tall buildings world-wide!

The fact is that urbanization and urban density is rapidly increasing world-wide and tall buildings play a significant role in addressing this growth. This is where tall buildings shine and have a considerable sustainability *impact*.



Figure 3. Skyline of Singapore.



Figure 4. 432 Park Avenue (New York).

4. Sustainability Impact of Tall Buildings

One of the precious resources required for building construction is land. Migration from rural and suburban to urban areas has perhaps the largest impact when it comes to land use. Further, at times, availability of land is very limited. This, in turn, results in tall buildings that are very slender to accommodate the needs of the area (Fig. 4).

An urban high-rise residential tower with 300 units may occupy a fraction of a city block while a suburban development with the same number of units with, say 1/8 acre lots, requires about 38 acres (15 hectares).

In addition to more land used for construction, suburban living requires significant additional land for roadways and for providing other infrastructure including supplying utilities and other services. And, unfortunately, often the land used for suburban development is productive agricultural land surrounding cities.

Tall residential buildings allow for efficient and concentrated use of utilities (Fig. 5) versus the very distributed systems needed for suburban living. Research conducted in the Chicago area (Du 2017) shows that, "The infrastructure length per person in Downtown is much lower than in Oak Park. Downtown uses 1.1 meters per person, which is only 12% of the 9.4 meters per person used in Oak Park." This characteristic of tall, more specifically tall residential buildings, results in not only substantial savings in initial amount of material and cost of providing such services, they significantly reduce the cost of maintaining these systems over a long period of time as well.

Typically, a considerable percentage of people who work in large metropolitan areas actually commute to work from



Figure 5. Lake Shore East Park (Chicago).

the suburbs. In addition, many others go to cities during the day for shopping, pleasure or for business reasons. In fact, it is not unusual for population of large cities to increase by as much as four or five times during the day versus the evening. This daily routine depends mostly on personal vehicles and roadway systems.

Urban density offered by tall buildings reduces the commute time and distance travelled from residence to work. In fact, research (Du 2017) shows that, "The total distance travelled to work per household during a typical week in Oak Park was 450.1 kilometers, 294% of the average value of the downtown residential towers, which was 152.9 kilometers." The same research found that, "Households in Oak Park spent 23.7 hours travelling on average during a typical week, which is 188% of that seen by Downtown households (12.6 hours)." Personal vehicles seem to be the most popular means of commute, certainly in the United States, for both urban and suburban residents.

Suburban living and longer travel to work translate to more roads needed as well as more road erosion and thus the periodic need for road pavement repair/replacement, more wear and tear of vehicles, more fuel consumption and more generation of harmful gasses from vehicles. Longer travel to work also translates to less time spent with family or on other enjoyable life activities. It is noted that sustainable development is not limited to ecological factors only, but social, and economic considerations as well.

Despite their higher rate of energy consumption and larger Carbon foot print, tall buildings as part of dense business districts offer potentials for higher overall energy efficiency in terms of energy use per inhabitant and a lower Carbon foot print. In fact, it has been claimed (Foster, 2008) that Manhattan, NY could be considered the greenest place in America because of such efficiency.

Urban density and big city work or living does not mean lower quality of life. In fact, while most residential or mixed-use tall buildings have amenities readily (and perhaps freely) available to their occupants, many suburban residents do not have such amenities at the same scale available to them. Further, availability of opportunities for entertainment such as theatres, cinemas, museums, art galleries, concerts, lectures, attractive views of the city, natural lighting, and other life's pleasures and activities may lead to happier lives for occupant of tall building. As noted earlier, the fact that more people move to urban areas and often live in tall buildings in central business districts of large cities indicates that people prefer this life-style and enjoy happier lives.

5. Taking Advantage of Opportunities

Tall buildings offer a number of unique opportunities for benefit in their design. For example, research (Song, 2012) shows that taking advantage of microclimate changes such as wind speed, temperature and humidity variations at high heights versus at the ground level can offer substantial benefits in the HVAC design of super tall buildings (Fig. 6). Leung and Weismantle (2008) investigated the application of temperature changes to super tall building with findings that would better inform and benefit the architecture of the building.



Figure 6. Burj Khalifa (Dubai).

Even the structural design of a tall building can lead to considerable potential benefits over the life of the building. For instance, consider a 60-story building. Reducing the floor thickness by three inches (76 mm) per floor may not result in the most efficient structural floor and may in fact increase the initial embodied energy of the building, but over the height of the building there will be a reduction of 15 feet (4.6 meters). This in turn translates to reductions in wind load and therefore less robust lateral load resisting system; reduced amount of curtain wall used; less heat gain or heat loss due to reduced glazing; less wall and partition material; less pipes and other HVAC material needed; and less volume in the building to condition during the life of the building. Alternatively, the building

may accommodate an additional floor over the same height, generating more space for occupancy and more revenues for the owner.

Design of tall buildings is a collaborative process involving multiple team members from architect to the designers of building systems as well as the constructor. This integrated approach also offers opportunities for design, construction and operation of tall buildings with even bigger sustainability impact.

6. Conclusion

Two key factors must be part of sustainability assessment of tall building.

- A comprehensive and integrated design and construction process with consideration of a Life Cycle Assessment (LCA)
- The tall building's context and role in the community in which it resides

Clearly, the first bullet point applies to buildings of all sizes. However, the second bullet point is what has been missing in our sustainability assessment of tall buildings.

Tall buildings are an integral part of today's business and life-style. If we need to assess their role from a sustainability point of view, we need to begin looking at the sustainability *impact* of tall buildings. We need to look outside the "box" both figuratively and literally!

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