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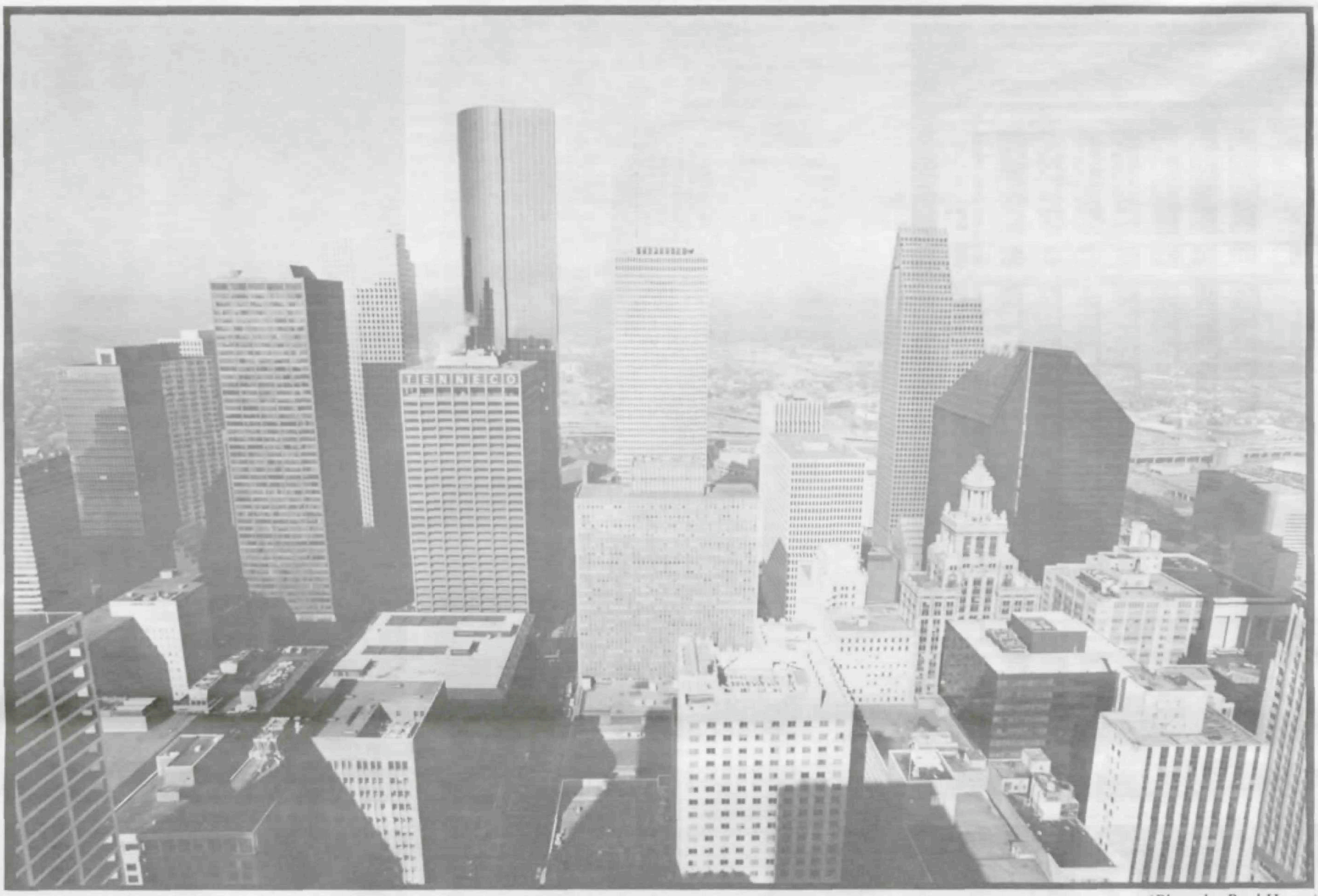
The Environmental Impact of Tall Building



(Photo by Paul Hester)

After an absence of some years, anyone who returns to an American city is inevitably surprised by the radical change that has occurred in its skyline. Indeed, the skyline of every major American city, with the exception of Washington, D.C., and Philadelphia, has been completely changed over the last 20 years by the construction of large numbers of high-rise office buildings. In addition, a number of *very tall* buildings (50 floors and up) have appeared in many of these cities. In Houston, several buildings of more than 70 stories have been built and an 82-story building with a projection approaching 100 stories in height is in the site-preparation stage. Wind-tunnel tests have been completed on a 160-plus-story building for Chicago. Other very tall structures are being proposed for Denver and New York. As it appears that the American city of the future is going to be characterized by large concentrations of tall buildings, it might be prudent to consider just what the long-term impact of these structures will be and what the consequences for the future of the city might be.

Long-Term Urban Impact
In 1978 the Chrysler Building was declared a National Historic Landmark. This is significant because it suggests that tall buildings have existed as a building type long enough to draw conclusions about their long-term life and their impact on the urban environment.

New York has the greatest concentration of high-rise buildings in the world. This concentration has existed for some time. It also has three of the tallest buildings in the world — the Empire State and the twin World Trade Center towers. Though Houston is a very different sort of urban environment, we might expect some of the general long-term effects of tall building observed in the New York example.

There is very little information available about the long-term economic life of tall buildings. From the relatively recent interest in rehabilitating commercial structures, it appears that buildings can have lives significantly longer than their first economic life. In New York, significant renovation in both commercial and residential structures has been taking place for some time. The bulk of the buildings being renovated predate the 1920s and are relatively small in size, which is related to the economics of renovation. Newer buildings have not generally been renovated but demolished. Most recently, preservation advocates have achieved landmark status for Lever House (Skidmore, Owings and Merrill, architects, 1952) to prevent demolition. Not only is this building only 32 years old, it has received world-wide recognition as one of the earliest and best examples of the modern slab office building. A similar fate awaited the Chrysler Building. After 1960 the owners of the Chrysler Building, Goldman-Dilorenzo Interests, could only service the huge mortgage on the building by effectively eliminating any maintenance on the property. This led to, among other things, the accumulation of 1,200 cubic yards of trash in the basement, numerous leaks, and other serious problems which drove tenants away and doomed the structure to certain demolition. It was saved from this fate only by a takeover by the principal mortgage holder, the Massachusetts Mutual Insurance Company, and the investment tax credit that landmark status made possible.[1]

There are many reasons that a relatively new structure of unquestioned architectural historic value such as Lever House might be demolished, not the least of which is the continued extremely high value of land in Manhattan. However, it is ironic that Lever House could not be renovated at less overall cost than constructing a completely new structure. Indeed, this is true for most high-rise buildings and if this condition is exacerbated by the height of the building, a serious future problem is created wherever there are concentrations of these buildings. In the case of the Chrysler Building the maintenance service was reduced and as a result many tenants decided to move. While the area around the building did not seriously decline in value, the building enjoyed a very negative reputation.[2] Would anyone have imagined this possible when the building was completed in 1927?

Another serious question regarding the impact of tall buildings is related to their effect on the surrounding urban environment. We all have observed the phenomena of lobbies crowded early in the morning and late in the afternoon but devoid of life at other times. The concentration of population in very tall buildings means that the street level must be allocated almost completely to circulation space. The little commercial space that remains is too expensive for small-scale retail operations that used to inhabit the street level. As tall buildings are constructed in larger and larger numbers, the surrounding streets become less populated and therefore less able to support small-scale commercial activity. In other words, a vicious circle is initiated in which fewer and fewer people have any direct interest in the public space. The street becomes an unused, and potentially dangerous, area.

Beginning in the 1950s a number of critics of urban planning — perhaps the best known of which was Jane Jacobs, author of *The Life and Death of Great American Cities* — warned of this disturbing development in the "modern city." They argued that the seemingly chaotic network of small businesses and mixed use that characterized the streets of the traditional city was an important social mechanism. Besides providing a stimulating environment, rich in random associations, the businesses had a vested interest in the safety of the street and supervised it as such. More recently, such observers of urban crime patterns as John Q. Wilson of Harvard University, have recognized a relationship between intermittent use, lack of supervision, and random violence.

The purpose of this argument is not to suggest that high-rise building is responsible for street crime. However, it does appear that this type of building contributes to a pattern having negative consequences. In recognition of this, New York zoning laws were changed in 1979 to mandate retail space on the street level of commercial structures[3]. Other cities have adopted "bonus" programs to stimulate redevelopment of the downtown street area.

Planning and Development Patterns
The tall building has become a component of the planning of American cities, especially those developing like Houston. In such localities as Dallas or Denver, this phenomenon happened under the watchful eyes of a planning agency, while in such others as Houston, the same phenomenon occurred exclusive of public controls.

In the 1930s and '40s planners began to realize that the flight to the suburbs would exert serious consequences on existing downtown areas. Urban design theory strongly supported the redevelopment of downtown areas in conformance with modernist planning ideals on the model of many European cities rebuilt after World War II. In the 1950s the United States government supported this goal by instituting the Urban Renewal Program that made possible the public condemnation and clearing of large tracts of downtown property. This laid the groundwork for the eventual commercial revitaliza-

tion that has taken place in many American cities. However, this process lent a distinctive flavor to the character of redevelopment. It was narrowly effective and favored large-scale projects of the type we have been discussing. Consequently, the single-minded and segregated planning of modernist urbanism and modern economics has produced downtowns that suffer from the same general problems: the lack of activity during the day and the threat of danger at night. As downtown redevelopment was accomplished, the reason for subsidizing downtown development ceased to exist. However, this planning trend has not been altered and the ideas of centralizing commercial functions and constructing larger and larger buildings to house them continues to be stimulated today by such programs as the Urban Design Action Grant Program (UDAG).

Houston is a good case in point of how strong the momentum for centralization has become. In 1974 the Environmental Protection Agency issued an ultimatum to the City of Houston to improve sewage treatment or stop new development.[4] The city's response was to declare a "sewer moratorium" on all new construction. In what often has been described as a "brilliant" stratagem, the city managed to trade plant capacity so that construction was limited to existing capacity in all areas but the central business district. In a small area, which included the CBD, no restrictions were imposed; the sewer moratorium did not exist. With similar logic, a metro system has been proposed that fixes, once and for all, the focus of development on the downtown area. Whether or not the system is economically justifiable, it represents so large a public investment that the city would be obliged to support growth along it.

Obviously, economically active downtown areas are important to a city's image and tax base. However, increased centralization supports a building type with questionable future consequences. Although concentration of commercial growth in center-city areas was important at one time, it may be that other strategies that support a variety of forms of development are preferable today.

Operating and Maintenance Costs
Prior to the 1973 Arab oil embargo, the management of the twin World Trade Center towers in New York boasted that the buildings (population 50,000) consumed more electrical energy than the city of Schenectady,

Theodore H. Davies Building, view of courtyard (Lost America, From the Mississippi to the Pacific, *Princeton, Pyne Press, 1973) A block square building configured around an internal court.*

New York (population 100,000).[5] This raises another disturbing issue of tall building: future users are compelled to perpetuate a high future energy-use pattern.

Research done by the Building Owners and Managers Association suggests that, on a national average, office buildings consume about 75,000 BTUs of end-use energy or 112,500 BTUs of source energy per square foot of office space.[6] At present, the construction costs of an average office building are exceeded by its utility costs in approximately 11 years. This has changed on the order of 300 percent, from a 30-year recapture as recently as in 1960.

All available information indicates that very tall buildings exceed these consumption figures by about 15,000 BTUs/sf of end-use energy, or 20 percent.[7] This implies an even more rapid capture of capital by operating costs in this building type.

There are many reasons why tall buildings consume so much energy. The elevators and pumps required to service the upper floors attach an energy-use premium to building height of about 10 percent. Another source of energy consumption is related to the sheer size and bulk of the buildings. While it is true that large-scale mechanical systems have some inherent efficiencies, they have difficulty handling variable-sized loads. That is to say the machinery is efficient when operating at 100-percent capacity but cannot operate efficiently when only a few floors or single offices require air-conditioning. During a typical year, the majority of operating time is in such a partial demand mode.

The largest environmental premium paid for very tall buildings, however, is a product of the scale and inflexibility of the floor plan. The greatest single consumer of electricity, and the greatest single source of heat that the air-conditioning system must overcome, is the lighting system. Almost half (about 40 percent) of the air-conditioning tonnage in high-rise buildings is provided to offset the heat generated by lighting systems. Consequently, air-conditioning may be required 12 months of the year, even in Chicago and New York. Many very tall buildings become larger at the base; other, slab-type buildings may maintain the same shape for their entire length. In either case, the sheer size of floor and depth of lease space virtually eliminates any possibility of using increased exposure to natural light to offset artificial-lighting requirements. Consequently the building form tends to "lock-in" the inefficiency of large buildings and prohibit increased efficiency at a future date.

In view of serious consequences in the future, why are these buildings still built? Many people assume that they are the inevitable product of the balance sheet and the real estate development process. There appears to be, however, a considerable body of evidence that suggests that high-rise buildings, especially very tall ones, are surprisingly subjective products, built as much for symbolic as financial opportunity.

Building Costs
There is no question that tall buildings are inherently more expensive than equivalent space in other height configurations. It is difficult to say exactly how much more expensive, because developers and clients are generally secretive about the ultimate cost of these projects. Preliminary cost information was available on the following Houston projects. It is generally accepted that the actual cost exceeded this amount by, in some cases, a considerable percentage.

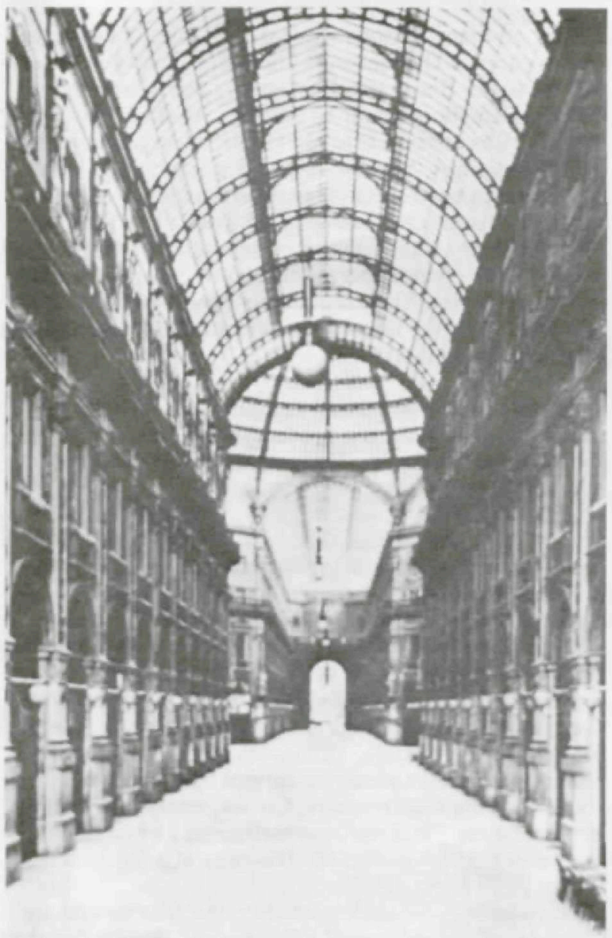
Available information would place the cost of a structure roughly comparable in quality and below ten floors at approximately $70/sf.[8] Therefore the very tall building represents an approximate 20 percent premium building cost over lower-building configurations.

The major component of this increment is the cost of the structural system. There have been a number of significant changes in the engineering of tall buildings that have led to a dramatic reduction in the amount of steel in very tall structures. The Empire State Building (1929-1931) used an average of 50 pounds of steel/sf of building area, while the Sears Tower in Chicago (1972-1974) used less than 15 pounds of steel/sf of building area. Much of this reduction was due to the pioneering work of engineers like the late Fazlur Khan of the Chicago office of Skidmore, Owings and Merrill.[9] Khan observed that the primary forces in tall buildings were induced by wind loading rather than gravity, and he developed the framed-tube system of wind bracing that is now utilized almost universally in high-rise buildings above 40 floors. Even at the theoretical optimum, however, Khan observed that the amount of structure must increase dramatically in response to building height. For example, a 60-story structure must utilize about 30 percent more steel/sf than a 20-story structure of comparable floor area.

Vertical circulation systems are another major cost generated by increased building height. Many buildings in excess of 40 floors use a dual elevator system incorporating low-rise and high-rise elevator banks. The low-rise elevators are conventional in design and serve the lower half of the building. Faster and more sophisticated elevators serve only the top floors of the building. Very tall buildings may utilize three sets of elevators through a sky lobby. Conventional elevators serve the building's lower floors and serve the highest ones from the sky

Recent Houston Tall Building Projects

Project	Developer	Date Project Announced	Floors, Heighth	Gross Area (in square feet)	Budget (in millions)	Cost per Square Foot
Texas Commerce Tower in United Energy Plaza	Gerald Hines Interests	14 April 1978	75 (1,002 ft.)	2 million	$145	$85
Allied Bank Plaza	Century Development Corp.	3 June 1980	71 (970 ft.)	2 million	$200	$100 plus
RepublicBank Center	Gerald Hines Interests	19 June 1981	56 (777 ft.)	1.5 million	$180	$120
Transco Tower	Gerald Hines Interests	8 July 1981	64 (901 ft.)	1.6 million	$200	$125
Southwest Center	Century Development Corp.	11 October 1981	82 (1,400 ft.)	2 million	$350-$400	$175-$200



Galleria Vittorio Emanuele, Milan, 1865-1877, Giuseppe Mengoni, architect (Architecture: Nineteenth and Twentieth Centuries, *Baltimore, Penguin Books, 1958)*

lobby. A third class of very specialized elevator travels directly from the ground floor to this intermediate lobby. This class of elevator is the largest, fastest and most expensive, averaging as much as $500,000 per unit as compared to approximately $100,000 per unit for the conventional type.[10] A building utilizing six of these elevators adds a premium of several million dollars to the construction cost, a cost directly related to building height.

A new premium for high-rise buildings in the Houston area has been generated by the new high-rise building code requiring sprinklers in buildings above nine floors. The nine-floor height is determined by the maximum access of fire department ladder trucks. There has been much public discussion of the fire danger inherent in very tall, sealed buildings. This in itself constitutes a serious criticism of very tall structures. While the sprinkler system cannot guarantee safety (cf. smoke-related casualty), it has been accepted for the time being as a sufficient fire-suppression device. The cost of a sprinkler system may add as much as $2/sf to the cost of a structure and this, too, is a direct cost of building height. Even with the provision of sprinklers there is significant evidence that fire safety still presents a serious problem in tall buildings. In all high-rise fires to date the highest proportion of loss of life has occurred due to smoke inhalation, and smoke generation will not always activate a sprinkler system.

These major expense areas, in addition to a number of others, result in high-rise buildings (especially very tall ones) that are inherently more expensive than lower-scale buildings of comparable quality. The premium seems to increase geometrically in relation to building height above approximately 10 floors. A 70-floor building may be 20 percent or even 30 percent more expensive than a building under 10 floors of comparable floor area.

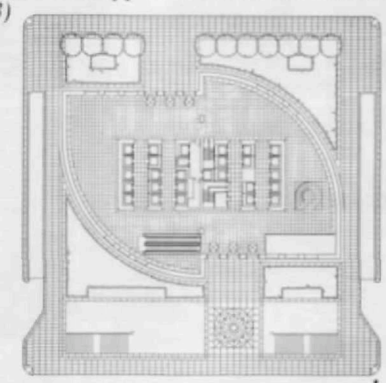
Highest and Best Use

The high-rise building has become a symbol of commercial success and the land-development process. As such these buildings seem to represent the "highest and best use" of real estate and the most profitable building investment.

When most people see a downtown area with a number of high-rise structures, they assume that the size of the structures is related to the price of land. More specifically, that the price of land is so significant a factor that the building area must be increased proportionately. It is interesting to investigate this conclusion with regard to an actual project in downtown Houston. A 62,500 square-foot land area, purchased previously by the owner, had a market value of about $12.5 million.[11] A building area of 1.5 million square feet was constructed on this site for approximately $85/sf or $127.5 million. This makes the cost of the site about $10/sf or less than 10 percent of the cost/sf of $85. How significant is this cost? It is no greater than the cost of any major subsystem of the building (structure, air-conditioning, elevators, foundations, exterior wall, lighting). The ratio of land to building cost is, in fact, far less than that used in other types of development such as housing, where land cost may be as high as 20 to 25 percent of project cost. Consequently, in the Houston area, land cost is not the major factor it may appear to be and can be compensated for by economics in the building subsystems. This suggests that land cost is not the only significant factor in the decision to build very tall buildings and that the ratio of land cost to building cost is often much higher in other types of profitable real estate development.

The profitability of very tall structures also requires

Theodore H. Davies Building, Honolulu, 1921, Louis Christian Mullgardt, architect, demolished. A block square building configured around an internal court. (Lost America, From the Mississippi to the Pacific, *Princeton, Pyne Press, 1973)*



Plaza level plan, Allied Bank Plaza, 1983, Skidmore, Owings and Merrill and Lloyd Jones Brewer and Associates, architects (Skidmore, Owings and Merrill)

reexamination. It seems ludicrous to suggest that these buildings are unprofitable, but this may in fact be the case in a number of projects. Their profitability depends on a delicate balance between the prestige of the building and the rental market. In many cases the buildings cannot be leased as quickly as expected or inducements must be offered to encourage leasing in such markets as the present one. In the opinion of a number of real estate developers, this is the situation in a majority of Houston projects built in the last ten years.

Such factors as these should discourage the proliferation of tall buildings in a free-market economy. Ironically, however, the tax system allows the loss of the building to be transferred to another financial entity to offset a tax liability. The loss may actually be "sold." The reasoning behind this provision is somewhat complex; the mechanism is intended to stimulate the building economy, functioning like the mechanism of depreciation. Once again this suggests that these very tall buildings are not the inevitable product of the real estate economy but are surprisingly subjective ventures, unwittingly institutionalized by, among other things, the tax system.

Other Issues

There are a number of issues that relate to personal satisfaction and productivity that we have not touched on. Perhaps the most important of these is the question of whether office workers experience psychological dislocation in tall buildings. There are a number of studies that indicate that people do become disoriented in high-rise buildings. They cannot easily distinguish what floor or even what side of the building they are on. Tinted glass tends to make it difficult to read outside weather conditions, further adding to this sense of dislocation.

While productivity has not been tied directly to this, studies indicate that workers choose, in overwhelming numbers, to work in lower buildings after working in high-rises.[12] So at the very least, there is a question about the fitness of high-rise building for the workplace that must be considered.

The Density Argument

One of the most often expressed arguments for tall buildings is that they are necessary to achieve density, and that the alternative is uncontrolled urban sprawl. This argument contains two implicit assumptions: that high density cannot be achieved with mid- and low-rise building and that the only alternative to the concentric city is uncontrolled and counterproductive urban sprawl.

The density argument depends first on establishing standards of acceptability. For this reason it is useful to compare the densities of existing cities. The densities of the core areas of Tokyo, Hong Kong, Peking, and Shanghai are all nearly equal or are slightly in excess of New York (800 persons per acre). Paris, London, and Rome have densities only marginally less than New York (650 persons per acre). Among these cities only Tokyo and Hong Kong have a high preponderance of tall buildings. Peking and Shanghai have almost no high-rise building and very high densities are achieved. In the United States, Washington, D.C. and Philadelphia have building-height limitations and still achieve densities within 75 percent of New York. Of course, there are tremendous differences in living patterns and space standards between Asian and European cities and between European and American cities. However, it is clear that high density can be achieved with a high level of amenities without tall or very tall building.

The concentric density argument is inherently more complex. According to this view, a city requires a core or center of appreciably higher density that its surrounding parts. This point of view is based on, among other factors, a reaction to suburban sprawl and a respect for the patterns of the traditional city. The argument, however, may be slightly simplistic. Whether the physical form of the traditional city is appropriate to the scale of population being housed in cities at the present time certainly is open to question. A detailed examination of cities like Paris, Rome, and London indicates that a more appropriate model may be a high but relatively uniform density with subcenters formed around such institutions as universities, churches, and markets. A considerable body of planning theory also has developed around the concept of a more dispersed city linked by transportation and communication. Frank Lloyd Wright's Broadacre City is only one early example. Auguste Perret, LeCorbusier, and others explored this concept as well. The implicit weakness, however, always was a rejection of the traditional city. Network plans never were seriously proposed as the more correct, scaled-up version of the traditional city. Most recently, however, the dispersed model of the city has received attention as an energy-related planning consideration. The argument here has to do with taking the entire dwelling-workplace environment into account. Over 50 percent of the total fuel consumption of the U.S. is generated by transportation whereas only about 10 percent is consumed by buildings.[13] The amount of energy consumed in individual buildings is negligible compared to the energy consumed in driving to and from the workplace in a city like Houston. A more energy-conscious planning approach might distribute commercial subcenters in order to reduce commuting time and thereby conserve fuel.

Conclusion

What patterns of development and building, then, might a more resource-conscious point of view support? In terms of the city, a more dispersed planning strategy emphasizing subcenters as opposed to a single center should be considered. In the City of Houston, the policy of allowing unrestricted utility connections in the downtown area only and the Metropolitan Transit Authority plan that focuses the system exclusively on the downtown area might be reexamined and modified to support growth in both the central business district and such existing subcenters as the Galleria, the Medical Center, and the Energy Corridor.

In terms of the individual building, there may be viable alternatives (with fewer negative environmental consequences) to very tall buildings to house large institutions and create memorable images. The model that has developed in other cities, where building height was limited by technology or convention, is the building complex, characterized by its developed outdoor or public space rather than its sheer size or bulk. The Galleria Vittorio Emanuele in Milan is an example of an enclosed street that gives access to some 250,000 square feet of interconnected commercial space. The architecture of the linkage system, rather than of the buildings, is memorable. The space has been used continually for almost 100 years. The relatively low-scale structures around such spaces can be serviced easily, accept changes of use, and inherently are more economic to build and operate. Modern communication techniques allow these spaces to be linked as efficiently as the vertical configurations. The distribution of density tends to support rather than abandon the commercial life of the street.

To take an extreme example, it can be demonstrated that the density of downtown Houston could be housed in a city limited to nine floors by increasing the area of the CBD by only 30 percent, and this provides for atriums or landscaped areas in the center of each block. It also can be demonstrated that the land cost averaged over such an area would be equal to or less than the land cost incurred in building at higher density on less area.

While no one in Houston would seriously propose a limit of building height or propose any fixed optimum, it is clear that both with regard to building type and urban development that our present models are far too limited. It also may be true that these limitations unwittingly are being institutionalized by municipalities, causing serious consequences for the future.

Notes

1. "A Close Call," *Forbes*, vol. 121, 24 January 1978, 31-32.
2. "Score One for Art Déco," *Forbes*, vol. 121, 17 April 1978, 14 and 16.
3. "Housing Quality Regulations, Zoning Resolution, City of New York, passed 1961, amended 1973 and 1979.
4. William H. Anderson and William O. Neuhaus III, "Trading Toilets: The Subterranean Zoning of Houston," *Cite*, August 1982, 12-14.
5. Richard Stein, *Architecture and Energy*, Garden City, Anchor Press/Doubleday, 1978, 65.
6. "1983 B.O.M.A. Experience Exchange Report on Income and Expenses," Washington, D.C., Building Owners and Managers Association, 1983.
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8. Percival E. Pereira, ed., *Dodge Digest of Building Cost and Specifications*, Princeton, McGraw Hill Information Systems Company, 1983.
9. Gene Dallaire, "The Quiet Revolution in Skyscraper Design," *Civil Engineering/ASCE*, vol. 53, May 1983, 54-59.
10. Information from the Otis Elevator Company, Houston.
11. Information from the Horne Company, Houston.
12. Donald N. Conway, ed., *Human Response to Tall Buildings*, Stroudsburg, Dowden, Hutchison and Ross, 1977, 51.
13. Stein, *Architecture and Energy*, 13.