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Dario Trabucco
Dario Trabucco is a professor of Building Technology at the IUAV University of Venice, Italy. He is involved in many research fields at the university, particularly through participation in the "my ideal city" project financed by the EEU 7th framework program.

In 2009 he obtained a PhD in building technology with a thesis entitled "The Strategic Role of the Service Core in the Energy Balance of a Tall Building." This research examines the implications of alternative service core placement in relation to the embodied energy and the energy consumption of a tall building. During this period Dario also spent two research secondments at CTBUH/IIT, and one in Paris Belleville.

Dario has taught tall building design in many courses at IUAV and also in Paris Belleville, where he tutored at the Master "La Tour Metropolitaine" program.

He currently publishes in national and international periodicals and peer-reviewed journals and regularly takes part in conferences on tall building related topics.

Paolo Fava
Paolo Fava completed the master studies at the IUAV University of Venice, Italy where he graduated in 2012, presenting a thesis on the causes and the recovery solutions for obsolescence in tall buildings. He is now a practicing architect.

Crumbling façades, asbestos, and outdated elevators are often cited as reasons to tear down tall buildings and create new skyscrapers. However, renovating a tall building is often a better option than demolition and reconstruction. This paper examines the reasons for the demolition of tall buildings in the United States, Canada, and Europe and makes recommendations for alternative approaches.

Tall buildings suffer from the passing of time, exactly like all other building typologies. But their aging is rarely caused by structural decay, due to the characteristics of the materials used to construct them – steel, concrete, glass, and aluminum. Instead, the decline of tall buildings is more often a consequence of functional obsolescence. Tall buildings must meet the expectations of occupants, in terms of internal comfort, functionality, environmental performance, and cost. In fact, tall buildings typically are icons of modernity and, except in very few cases, such as the Empire State Building or similar "historically iconic" towers, they do not represent assets in themselves, but are simply seen by tenants as business facilities.

Only the most visible and distinctive tall buildings offer tenants long-term value. For example, on a low-rise scale, the historic and social appeal of an old Renaissance building may provide a marketing opportunity to a bank or a public institution, which in turn might ignore an inefficient floor plan or the lack of complete environmental comfort. But if the headquarters of a large firm or a bank is located in a modern office tower, optimal working conditions are expected, and the building is required to meet very high standards to retain the tenant and its end-users, the employees, in a competitive market. This is even more important for hotel towers, where the end-users, the hotel guests, literally change every night, and poor comfort conditions may result in customers not returning.

> "Depending on the extent, the renovation of a tall building can cost 50–90% less than the demolition of the present building and the erection of a brand-new tower of a similar size."

Lack of Decisions vs. Pros of Refurbishing

The decision on how to handle a deteriorating facility is a critical moment in the life of a tall building (Sloman & Edwards 2012). Undertaking upgrades can significantly impact the economic sustainability of the building. When the building requires a complete interruption of business due to renovations, tenants are forced to relocate to other facilities, and it may be difficult to attract them back or to find new tenants when the building reopens. This may prevent the building owner from undertaking the required work, and the decision is usually made in conjunction with the end of a significant tenant's lease.

The intervention is even more complex for multi-tenant buildings, where small tenants continue to come and go. The progressive decline of the building performance or the difference with competing buildings in the same area often results in an increase in the vacancy rate and a decrease in the profit for the investors.

If the decision is not taken to renovate – or the renovations are not economically justified by the market's needs – owners can make the dramatic decision to leave the building vacant, leaving the tower as an empty giant until the necessary funds are found. This is a very rare

Name	Built in	Height (m)	Height (floors)	Abandoned since	Reasons
Ryugyong Hotel, Pyongyang	1992	330	105	1992	Structural issues
The Sathorne Unique, Bangkok	1990	164 (est.)	50	1990	Never completed, due to recession
Torre Insignia, Mexico City	1962	127	25	1992	Lack of interested tenants due to recession
Sterick Building, Memphis	1930	111	29	1980	Excessive renovation costs
Torre Galfa, Milan	1956	109	28	2006	Asbestos, inefficient floor plate and elevators
211 North Ervay, Dallas	1958	76	20	1995	Lack of marketing appeal
Chicago Motor Club Building	1928	72	17	1996	Converted to residential units, unsold
Statler Hilton Hotel, Dallas	1956	71	20	2001	Low ceiling height, asbestos
Lady Luck Hotel Casino, Las Vegas	1964	82 (est.)	17	1998	Structural issues

Table 1. Examples of vacant buildings worldwide.

circumstance, but there are a number of significant examples of vacant buildings worldwide (see Table 1).

The abandonment of a building is a temporary decision that the owner takes waiting for improved market opportunities before a demolition or refurbishment of the building.

The Case Against Demolition

The demolition of a building generally occurs when there are no viable options to keep it as it is. This may be a consequence of a completely inappropriate technical aspect (i.e., a very low floor-to-ceiling height that prevents any installation of new equipment) or when the expected value of a new building (i.e., with a different use or an augmented rentable area) outweighs the demolition and construction costs.

Demolishing a tall office building is a very complex task, especially in dense urban environments. The technical difficulties are even higher if the building has a concrete structure that transforms the piece-by-piece deconstruction process typical of steel buildings into kinetic demolition work. The use of explosives in these cases represents the cheaper and quicker solution, but that is often not a viable option in dense urban areas, considering the potential consequences for the neighboring buildings and underground infrastructures as well as the dust, noise, and vibrations generated by the demolition (Mizutani & Yoshikai 2011).

Another important consideration is the waste of construction materials produced by the demolition. Many building materials can be recycled to produce new materials, thus recovering the energy they embodied during their production. On the contrary, other materials cannot be recycled (bricks, tiles, coated glass, concrete, etc.) and they can only be used as infill materials for civil engineering projects such as roads, or disposed of in a landfill. The energy that was used to produce such materials is therefore wasted forever.

As a consequence, the restoration of an existing building represents not only an economic opportunity, but also a sustainable practice for reusing the embodied energy contained in building materials.

Building part	Average cost	Probability to be modified. 0= Very unlikely; 2=very likely
Frame & upper floors	20.6%	0
Design & on-site costs	19.9%	Variable as a share of cost
External walls, windows & doors	18.4%	2
MEP	16.5%	2
Lifts & stairs	7.7%	1
Substructure	7.6%	0
Internal walls, partitions & doors	5.8%	2
Floors & ceiling finishes	1.9%	2
Furniture & fittings	1.6%	2

Table 2. Average cost of tall building renovation (Source: Watts & Kalita 2007. Data modified by the authors).

The Case for Renovation

Depending on the extent, the renovation of a tall building can cost 50–90% less than the demolition of the present building and the erection of a brand new tower of a similar size. Cost models for tall buildings (Watts & Kalita 2007), detail the economic relevance of those parts of the building that, in a typical renovation, are likely to remain almost untouched and unrelated to the intervention cost (see Table 2).

But there are other advantages to a building renewal compared to the erection of a new tower. In many cases, the restoration of a building takes less than half the time required for demolition and new construction. The speed of the refurbishment can provide a faster response to market needs, resulting in a more successful investment.

From the point of view of sustainability, the renovation of an existing building affords important savings in building material, as large parts of the existing building, including foundation, structure, and cores, are maintained. The energy needed to tear down the old building, clear the site, and produce and transport the new construction materials can be saved, reducing the embodied energy of the restored building.

A New Study

For the purposes of this paper, a survey was carried out on all buildings exceeding 200 meters in the United States and Canada (188 buildings) and all those exceeding 100 meters in the European countries (651 buildings). It was found that a total of 81 buildings had experienced significant renovations. Of those, the authors were able to collect information about the ameliorations introduced and the causes of the necessary interventions in 60 buildings (see Table 3). On average, major works were needed 33 years after the buildings' completion, but many cases of earlier repairs or improvements can be found.

As noted, market needs are the leading force behind all kinds of interventions, as the building must meet the user's expectations in terms of performance, in order to maintain its commercial soundness. Tall buildings are highly speculative investments and owners pay a great deal of attention to the vacancy rate index. Very tall buildings need to attract and retain big tenants to maintain occupancy for very long periods. For this reason large tenants such as law firms, consultancy offices, and banks often have the leverage to convince the owner to adapt the building to their needs. Among the causes of obsolescence identified, many apply to all building typologies, while some are specific to tall buildings, as their importance or the complexity of the required interventions is increased by the verticality of the tower. We now concentrate on three distinct aspects of intervention in tall buildings based on their importance, their frequency, and their impact on the building use:

The Vertical Transportation System

The vertical transportation system is one of the distinctive features of a tall building. Although the importance of elevators is often underestimated, their low performance can be the reason for the economic problems of a high-rise development, such as the case of the Woolworth building, which was famous for the poor capacity of its elevator system (Weisman 1970). For this reason, the performance of vertical transportation systems are carefully assessed from the early design stages of a tall building, sometimes even influencing its massing and shape. As with all building components, the vertical transportation system suffers from aging. However, with proper maintenance, it is hard to detect a decrease of performance during operation, and its operational safety rarely jeopardized. The only noticeable problem, from the point of view of the building manager, is related to the increased frequency of maintenance, while the daily user will only notice the decay of the cabin materials.

The lifespan of an elevator system is usually quite long, compared to other building elements. Usually, elevators are renovated on average every 40 years, though it is not uncommon to find elevator systems older than 60 years, provided that the building maintains its usage characteristics.

However, it is interesting to note that some circumstances may require a more complex intervention. Rather than the actual decline of the transportation properties, the need for an intervention on the transportation system can arise from the changing needs of the building's users. The most complex case is the modification of the internal function of the building, for example: an office tower transformed into a residential building, or a single-tenant office building repurposed into a multi-tenant tower. In these cases, a complete change of the elevator system is required and the changes can have a significant impact on the building layout.

More often, the vertical transportation system is renewed to meet the updated requirements of the building users, in terms of better performance, increased comfort or lower energy consumption. For example, the energy needed by elevators can be transferred to the building as heat: a better performing elevator saves on operating energy, but it also reduces the heat load on the air conditioning system.

An increased awareness of the energy efficiency of buildings is now driving many renovation projects. A recent example is the Empire State building, which experienced an increase in the vacancy rate in the past decade, as a large number of tenants moved to more modern and efficient buildings. The building owner invested more than US$500 million to modernize the building, including a

Cause of intervention	Incidence	Type of intervention	Notable examples
Façade renovation caused by decay of the curtain wall properties, or change in architectural style	41%	Substitution of the curtain wall with similar or different elements	Pirelli Tower, Milan; Lake Shore Drive Apartments, Chicago; Lever House, New York; Tour Europlaza, Paris; Stock Exchange Tower, London
Internal ameliorations, change of use, modification of the building mass/volume	21%	Alterations to the building mass or internal spaces to meet new/different market needs	Tour First, Paris; Tour TSR, Paris; Empire State Building, New York; Blue Cross Blue Shield Building, Chicago & GE Building, New York
HVAC underperformance, excessive costs, improvement of energy efficiency	15%	Improvement of the environmental performance of the HVAC systems	60 Wall Street, New York; Empire State Building, New York; Deutsche Bank, Frankfurt & Torri Garibaldi, Milan
Building health	11%	Removal of asbestos	Tour Montparnasse, Paris & Bank One Tower, Fort Worth
Poor lift performance, new tenant needs	7%	Substitution of cabins/ lift engines, upgrading of the control system	Chicago Board of Trade, Chicago; Torre Picasso, Madrid & Empire State Building, New York
Structural issues/threats	4%	Reinforcements, substitutions of structural elements	Citigroup Center, New York & Hancock Center, Boston

Table 3. Examples of recent renovations on buildings 200 m+ in the US and Canada and buildings 100 m+ in Europe.

Figure 1. An advertisement promoting the use of asbestos for building construction, c. 1981.
© Asbestos Corporation Limited

Figure 2. Bank One Tower, Forth Worth damaged by tornado in 2000. © Jesse Rangel

> “Rather than the actual decline of the transportation properties, the need for an intervention in the transportation system can arise from the changing needs of the building’s users.”

radical restoration of the building’s 68 elevators. Otis modified the traction and the control systems of the cabins, improving the transportation performance and reducing typical travel times by 20–40%. The energy consumption of the system was cut by 70%, thanks to a re-generation system that converts the kinetic energy of the moving cabin into electricity. The modern elevator system adopted in this case offered building managers a greater degree of flexibility. In fact, the traffic distribution can be re-arranged with a simple software update, allowing managers to modify the system performance to meet the user needs. The system is also capable of adapting automatically to varying transportation needs throughout the day.

A radical modification of the elevator system can be done only during major restoration work on the building. In fact, the different elements of the service core of a tall building are closely connected. For example, the corridor between two groups of elevators is often used to site the rest rooms on each floor. A change in the elevator system requires a change in the use of this space. For this reason, major modifications are done only in conjunction with a full refurbishment of the building.

A Hidden Threat: Asbestos

Before being recognized as a cause of cancer, asbestos was widely used in the construction industry for its thermal insulation capabilities and other properties that facilitated its use in concrete-based products, paints, and a wide range of building materials (see Figure 1). Asbestos is now a recognized threat to the health of building occupants, and its removal is a difficult and expensive operation.

Skyscrapers present a wide range of asbestos problems directly connected with their height and organization, and the lack of storage space and the possible consequences on the building use.

Ideally, a complete interruption of the building operations is the simplest strategy to deal with asbestos issues. But in large buildings the asbestos-removal operation can take several months or years. For this reason, a staged intervention is generally performed, allowing the continued use of the larger part of the building while the asbestos is removed from a limited and well-restricted area. The removal of asbestos requires particular care to avoid the dispersion of microfibers into the air. The operation can be particularly complex in fully air-conditioned buildings, as the asbestos particulates can be transferred to the occupied spaces by the mechanical ventilation ducts.

Notable examples of asbestos disposal in tall buildings include the interventions on the Bank One Tower in Forth Worth and the Tour Montparnasse in Paris. The Bank One Tower is a 149-meter-tall tower completed in 1974. On March 28, 2000, the building was hit by a tornado that severely damaged its curtain wall, causing most of the glazed panels to fall on the streets and surrounding buildings (see Figure 2). The damaged building was scheduled to be torn down, but the widespread presence of asbestos required a complete elimination of the cancerous material before demolishing the tower. Instead the building owner decided to maintain the building, remove the asbestos, and transform the remaining structure into a residential tower. The removal required an investment of US$65 million and took 10 months, with an average rate of 10 days per floor. In order to prevent the diffusion of asbestos fiber, the building was wrapped with a plastic envelope, and the operating crews removed the asbestos with pressurized water guns. The indoor air was constantly filtered, and the internal air pressure in the building was maintained at a lower level than the exterior pressure, avoiding leaks that would have sucked out the asbestos fibers. The building was subsequently refurbished and reclad, and it is now a successful residential development.

However, perhaps the best example of asbestos removal as an alternative to demolition is provided by the Montparnasse Tower. The building was determined to present an asbestos threat to its occupants, with several floors assessed at “Level 3” pollution, the highest degree of danger. The news sparked a sudden increase in the vacancy rate of the building and forced the owners to plan for the complete elimination of the asbestos.

The closure of the building during the removal process would have caused dramatic economic consequences for the owners, as the duration of the necessary work was estimated

Figure 3. Montparnasse Tower, Paris – external elevator.

Figure 4. China Resources Building, Hong Kong – before (left) and after overcladding. 🅭🅯🄎 WING / Peter0912

Figure 5. CIS Tower, Manchester – solar panel cladding. 🅭🅯🄎 Gene Hunt

to exceed 36 months. Therefore, the owners opted for a phased intervention. Sections of the building had to be emptied in sequence, in order to allow for the complex removal operations, without affecting the normal use of the remaining parts. The floors affected by the operations had to be sealed to prevent any diffusion of asbestos, particularly through the ventilation ducts. The elevator shafts presented a complex problem, as the stack effect proved to be particularly strong. The asbestos was disposed using two external elevators installed on the west elevation of the building, in order to avoid interaction with the building occupants (see Figure 3). The whole intervention, including an upgrade of the internal finishes of the building, will cost more than US$140 million, while the costs related to asbestos-related operations is expected to reach US$40 million. The phased removal strategy led to a longer renovation period, but it allowed the owner to retain most of the building's tenants.

Façade Renovation

The façade system is the major building component that most often requires renovation or repair. The sealing elements of façades suffer from heat stresses and solar radiation, and their performances decrease in a relatively short time, causing the penetration of rain, air, and dust. Envelopes are also renewed when better environmental performance is needed, and the façade system is replaced by modern, better-performing enclosures. In many cases, the façade renovation is also an occasion to refresh the architectural appearance of the building to be more contemporary (Patterson et al. 2012).

When the magnitude of the work surpasses the simple maintenance of the existing façade, the following definitions are used to characterize the level of renovation:

- *Refitting:* Complete or partial substitution of the façade element, with new elements that don't modify the architectural appearance of the building.
- *Overcladding:* Addition of a second "layer" of façade, in order to modify the architectural appearance of the building. This usually maintains the serviceability of the internal spaces, as the intervention is done from the exterior.
- *ReCladding:* Complete substitution of the existing façade with new elements that may also modify the architectural image of the building. Such modifications generally are meant to increase the façade performance.

While recladding and overcladding are more common than refitting, the latter represents the only viable solution for historic or iconic buildings, whose architectural appearance cannot be altered and must be preserved. For example, the envelope of Mies van der Rohe's Lake Shore Drive Apartments in Chicago, USA presented several aging problems after 50 years. The interventions on these seminal buildings left the original glass panels almost untouched (Cedro 2009). In contrast, a more incisive intervention was done a few years earlier on Skidmore, Owings & Merrill's famous Lever House in New York. SOM was commissioned to restore the initial appearance, which had been lost over decades, due to unsympathetic repairs that included different types of glass planes. The distinctive curtain wall was redesigned to meet the present-day energy codes without affecting the building's original appearance from the early 1950s. The choice of substituting single-plane glazes with a better-performing double-glazed system was initially opposed by the local authorities, over concerns the renewed building would look slightly different than the original.

Overcladding is typically used to improve a building's environmental performance. The China Resources Building in Hong Kong is one example, where the façade elements were partially backed by a second layer of glass to enhance the environmental performance of the curtain wall (see Figure 4). Another notable example, based on the quality of the achieved results, is represented by the CIS Tower in Manchester, United Kingdom (see Figure 5). This building features an external service core. The solid concrete walls containing the elevator shafts where originally covered with small glazed tiles. After 40 years, the decorative surface was showing some structural deficiencies with missing elements, detached parts, and de-colored tiles. A layer of almost 4,000 square meters of photovoltaic panels were added to the façade, allowing the production of 180 MWh/year, at a total cost of £5.5 million.

Recladding is the most radical kind of intervention, as it usually results in a totally different-looking building. There are countless examples of this approach. However, when such an important intervention is utilized, it typically includes a similarly radical overhaul of the interior of the building, including a revamping of its mechanical systems, fixtures, and internal layout.

A Case Study: Torre Galfa, Milan

Torre Galfa, a 109-meter-tall building designed in 1956 by Melchiorre Bega, is an example of a building facing renovation vs. demolition issues (see Figure 6). Torre Galfa had been vacant since 2006. The building suffered from many of the common problems found in buildings of that era: poor energy performance, outdated elevator systems, asbestos (removed in 2007), and leaking façades.

An analysis carried out for this building found a poor net-to-gross floor area ratio, resulting in inefficient floor plates. Also, elevators provided inadequate service if compared to the dimension of the building. Torre Galfa represents an interesting example of tall buildings of the period, and its demolition is strongly opposed by the public and architectural associations.

However, the above-mentioned issues discourage new tenants, with newer and better-performing tall office buildings available in the surrounding areas. The improvements proposed by this academic study (see Figure 7) are meant to increase the marketing appeal of the building, without drastic modification of its architectural appearance.

The proposed intervention aims to maintain and reinforce the original structural system, expanding the floor plates on the west façade of the building. In order to maintain the proportions of the building, four floors are added, using lightweight polymeric load-bearing structures. The service core is entirely re-organized, into a system with two zones and more elevators. Calculations proved that this solution will allow the building to host a large single tenant in the upper 15 floors, and multiple tenants in the lower part.

The proposal maintains the same façade design of the original tower, but inverts its geometry, so as to solve the user complaints about mullions obstructing the view when sitting at their desks.

Conclusions

Obsolescence is a threat to the market value of many buildings built after the end of World War II. Newer and more efficient buildings are attracting tenants with better comfort levels and lower running costs. But demolition is not always the best approach for aging buildings.

Builders, designers, and component manufacturers are increasingly exploring available alternatives, leading to the renovation of more tall buildings, instead of demolition. Research illustrates the renovation of a tall building can lead to a number of advantages. It is cheaper than a complete reconstruction and provides a quicker answer to market needs than a demolition. ■

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Figure 6. Torre Galfa, Milan transformation. © CTBUH/ Dario Trabucco

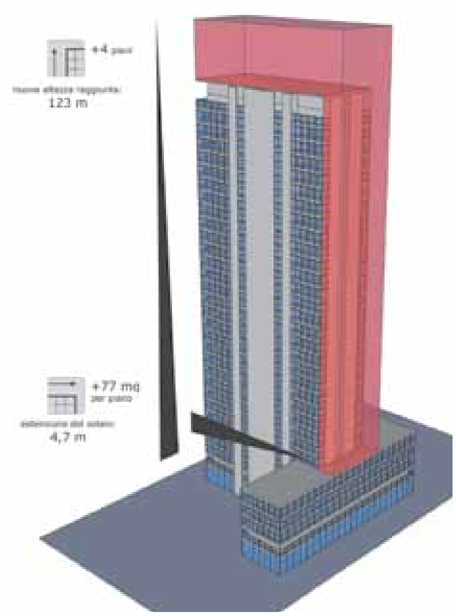

Figure 7. Torre Galfa efficiency analysis.

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