Lift and the City: How Elevators Reshaped Cities

Abstract

We are now living through the most dramatic change in the human history, as far as population and urbanization is concerned. In 1969, the rural population accounted for about 70 percent of the global population. By 2069, urban population will account for more than the same percentage. With half of the world’s population already living in cities, we are in the midst of the most significant demographic shift in modern history. The rising density of urban areas requires the development of more mid-to-high-rise buildings, which allow for the most environmentally friendly and cost-effective usage of space. Tall buildings are becoming more like vertical cities, providing office, residential and commercial space. Just like any other place in a city, every location within a building needs to be well connected if it is to attract commercial investors, tenants, and shoppers. To achieve this level of connectivity, buildings need future, flexible transport systems, similar to a metro.

Keywords: Digital Twin, Energy Management, Robotics, Ropeless Elevator, Skybridges, Urban Mobility

Introduction

The dramatic changes that will characterize the near-term development of future cities require quantum leap in the technology used to transport passengers and goods, to achieve the highest possible performance in buildings, where space is at a premium.

The elevator enabled the skyscraper and its dynamic development over the last century, but at the same time, this technology is limiting further progress in height and shape today. With the reinvention of the elevator and the full integration into the digitized building, the next incremental—and radical—steps in the story of lifts in the city are at hand, changing the shape of cities once again.

Multiple Cabins Per Shaft

A first major step beyond the traditional single cabin in a single shaft was the introduction of a second, independent car operating in the same shaft (Thumm 2004). One such system, TWIN (see Figure 1), features two cars operating independently in one shaft, making efficient use of available space while transporting up to 40 percent more passengers than conventional elevators. Each TWIN elevator has its own major mechanical and electrical components, but shares the same guide rails and landing doors with other cabins in a single elevator shaft. By reducing the number of necessary shafts, additional floor space is given back to the building, creating additional leasing opportunities. The Coda building in Atlanta, for example, features 10 TWIN elevators in five shafts.

Worldwide, there are more than 50 buildings with approximately 200 TWIN elevators installed, with many more are expected to follow. Further installations are planned at Hekla Tower in Paris’ La Défense district, Sunshine Insurance Group’s new headquarters in Beijing, as well as in two new towers in the financial district of Chengdu.

Although multi-cabin/single-shaft technology is well established in the market, another step was needed in order to keep pace with the multidimensional scope of urban development.
Ropeless Elevator Systems

The long-awaited ropeless elevator system affords the freedom to use a variable number of cabs in the same shaft, and to move the cabs not only vertically, but also horizontally within a fully flexible matrix of transportation routes through a building (Jetter & Gerstenmeyer 2015).

MULTI (see Figure 2) has the potential to truly revolutionize building design, offering total freedom to architects and building developers to create the best places to live and work, while improving the business case for multilayered, city-scale tall building developments. For many decades, architects and planners have envisioned vertical cities (King 2016), but these concepts will be much closer to feasibility with the introduction of the next generation of vertical and multidirectional transportation systems.

A ropeless elevator system that allows cabs to travel with narrow clearances and to change directions (see Figure 3) brings the monopoly of the conventional roped elevator to an end—160 years after its introduction. Linear motor technology allows cabins for the first time to travel vertically and horizontally in a building.

Numerous projects worldwide are planned to incorporate such a revolutionary system. The MULTI system is on its way to market and is being finalized in a new test tower in Rottweil, Germany (Jetter 2018) (see Figure 4).

In order to support architects, building planners and consultants introduce this new technology, a joint research project between the CTBUH and thyssenkrupp Elevator AG was performed to elaborate the potential for multidirectional transportation in tall buildings. The resulting report (Belmonte, Trabucco & Schöllkopf 2019) (see Figure 5) starts with an impressive historical overview of elevators and how they...
have changed the shape of cities. Following a chapter on contemporary innovations, is a section showing theoretical models of ropeless and multidirectional elevators. These case studies explore how these new elevator technologies can enable cities to be more interconnected, efficient and accessible.

**Performance Improvements to Conventional Elevator Systems**

Given the scale of the problem outlined above, it should be emphasized that one technology, however revolutionary, will not be enough to manage the challenges of urbanization in the next decades. Even more innovative technologies, and importantly, their cross-linking, will be required. What can we expect for the future of sustainable cities in the next five years, let alone the next five decades?

Alongside new technologies, there has been a continuous and incremental improvement of conventional, proven products and solutions in the elevator industry. The vertical transportation business is looking into the improvement of components like suspension means, traffic control algorithms (Gerstenmeyer & Peters 2018) and ideal combinations of different lift systems, such as single-deck (see Figure 6), double-deck, multi-cab/single-shaft and ropeless systems (Jetter & Gerstenmeyer 2015). Whether the discussion is about new or conventional systems, the trend is toward smarter, greener systems that are better integrated, safer and more efficient.

“Better integrated” can be further defined as an understanding that the elevator system is not a stand-alone technology within a building, but a nerve center in the ecosystem; one which adds a flow of data from sensors to a network, feeding into a “big data” pool, from which the building management system (BMS) draws insights through powerful machine learning and artificial intelligence. Through this level of integration, we are able to make the capabilities of the transportation system, energy, people flow, emergency response systems and other connections to the infrastructure of the city as optimal, as self-learning and adaptive as possible.

**Traffic Algorithms and Improvements to Quality and Quantity of Service**

Traffic management algorithms have been continuously improved, incrementally, for years. However, the introduction of a ropeless, multidirectional system warrants a new approach and basic research in this arena (Gerstenmeyer 2018).

These modern lift systems have opportunities and constraints for control algorithms, driven by existing and additional quality of service criteria. These additional criteria have rarely been considered in existing literature, control algorithms or traffic analysis.
The overall aim of Gerstenmeyer’s 2018 research was to determine and analyze existing and new quality of service criteria for destination control systems and multi-car lift systems, in terms of traffic handling and developing lift control concepts, considering these criteria.

**Energy Management Optimization for Elevators**

Another powerful factor to consider with respect to elevators is the energy management strategy for a building. High-rise elevator systems are not the predominant consumers of power in a building, but they typically have a very high ratio between starting and nominal current, which is a cost-intensive peak power demand. Therefore, not only do the transportation service aspects of the elevator scheme need to be managed, but also the power consumption. High-rise elevators, with their very high moving masses, need very high peak currents in the acceleration and deceleration phase. Both energy flow directions—power demand and power recovery—are critical for the grid, and the worst case needs to be considered for dimensioning the transformers, cables and standby power supplies.

Smarter and more energy efficient solutions manage the power demand locally by introducing the latest energy buffer technology (e.g. super capacitors, flywheels, and accumulators), together with self-tuning networks. This can lead to enormous peak power reduction, which in effect drastically reduces the connected load of electrical systems in a building.

The latest trend in manufacturing plants is to introduce DC-power networks for a better, more decentralized energy management system (Appuun et al 2018). This technology has been applied in the MULTI transportation system with high success, reducing peak power consumption by 60–70 percent and contributing to the “smart grid” (see Figure 7). This can be considered a viable smart solution for the benefit of all stakeholders around the building as far as costs, energy efficiency and sustainability are concerned.

This trend is expected to find its way into the building industry, revolutionizing comprehensive energy management in buildings, reducing losses and peak power as well as costs and volume for the whole infrastructure, including transformers. This is the base for smarter net-zero buildings, where the total amount of energy used on an annual basis is roughly equal to the amount of renewable energy created on the site. Renewable energy sources like photovoltaic systems are already powering DC networks, making the interface and transfer losses minimal.

**Interconnected Systems: BIM, Digital Twin, and Skybridges**

Interconnected systems are always benefiting from performance improvement effects. This applies for systems like Building Information Modeling (BIM) and concepts such as the digital twin, but also for huge physical structures like buildings and towers interconnected by skybridges (see Figure 8).

Although BIM and digital twins are already well-known and becoming more prevalent in the tall building industry, the full potential has so far been unrealized. Only a few projects worldwide achieve the holistic condition in which BIM is a management tool, not only for joint planning and interconnecting all physical data in a building (see Figure 9), but also improving the construction and operation phase.

In this condition, it becomes clear how powerful the interconnected knowledge of systems in a building can be, and their influence on economic, environmental and sustainable performance can be easily deduced.
Again, elevator systems can contribute a great deal of performance data, maintenance prediction and people flow patterns, which increases understanding of the complete ecosystem. Through this, we can optimize building management decisions, leading to lower waiting times, reduced downtime of vital systems, and increased energy efficiency (see Figure 10).

The development of interconnected buildings with skybridges also presents another trend, and an opportunity to improve performance. Here, the ropeless and multidirectional transportation system is of very high interest. There are high-potential concepts for improvements to building structures, such as the provision of alternative escape routes, new possibilities of balancing transportation capacities, and the increase of availability. A new research project, “Skybridges: Bringing the Horizontal into the Vertical Realm” has been initiated by the CTBUH to investigate the design possibilities of skybridges in the context of rapid urbanization and improvements in transportation and other technologies.

**Overarching Trends in the Building Industry, Beyond Elevators**

Even these impressive improvements in performance and comfort will not be enough to truly propel cities to where they need to be in 50 years. What can we expect beyond the improvements of digitization, BIM, digital twins and data analytics?

The need to construct millions of additional housing units also requires a drastic reduction in construction time. Prefabricated modules with highly precise details and consistent quality can help to build more organically and synchronously. The elevator industry will have a steeper adoption curve to this new environment than other participants.

Taking the example of elevator installation, traditionally the process starts with completion of the shaft’s total length. Some promising amendments to this process have transpired. Installation processes have been improved by starting to build up the first components after a hoistway has reached a height of between 50 and 100 meters. Guide rails, brackets, buffers, tensioning devices for compensation ropes, car sling, and cabin are the main parts of this sequenced procedure.

Further improvements include “shaft-climbers” that construct an elevator system floor-by-floor alongside the core construction, while providing installation platforms above the operating lift. The construction lift system, growing at the same pace as the overall building, can operate at the nominal speed of the final elevator system.

With the introduction of ropeless elevator systems, a more radical approach is expected, using robots and cobots (collaborative robots) in the installation process, not only for preparation work, but also for assembly, adjustment and quality checks.

Intelligent co-bots augment human experts and reduce their time on site. Other expert assistance systems for the on-site workers include virtual-reality (VR) and augmented-reality (AR) glasses. VR and AR guarantee a smooth and faultless installation process, making sure that all modules find their correct place in the shaft and are automatically recorded and confirmed by the BIM model.

**Additive Manufacturing**

The world has already seen its first building projects to use additive manufacturing (AM) methods, and universities are pushing forward with research projects to explore this production method for future use (Kulla Design 2018).

Also, different components in the elevator production supply chain have applied AM with some success. However, this technology is still waiting for its breakthrough, and needs to be monitored over the next few years for applications in real business cases.
High-Level Technology and Buzz Words

All these “buzz words” apply to the relatively small universe of architects, building planners, owners, suppliers, service and maintenance industry people who comprise the built environment trade. Each segment has solutions and applications that have brought us to today.

However, never before have these technologies required a seamless link between the disciplines. BIM is a prerequisite today for building planning, but it also needs to be pushed beyond the planning phase of a building, into the construction phase, and most importantly, into the operation phase. The CTBUH expert platform should acknowledge the effort to link different industries for truly “smart” buildings with interconnected, self-learning systems (see Figure 11).

The building is a huge ecosystem, with the potential to perform better as a whole if all subsystems are feeding the same cloud-based machine-learning infrastructure, and using the same database for the best possible decisions around energy and people flow management, service and maintenance. Although many building projects have achieved remarkable results on successful approaches with a digital twin, there is still a huge potential to be exploited.

Conclusion

The elevator gave birth to the skyscraper and has changed the shape of cities. The rapid growth in the size of cities and height of buildings has increased the pressure on this industry to improve performance of a system that hasn’t changed much over the last 160 years.

However, both incremental and radical changes have been made and will continue to reshape cities. Ropeless elevators for multidirectional transportation in tall buildings are making their way to the market. Further incremental developments and improvements in the areas of suspension means, traffic algorithms, user interfaces and energy management systems brought the state of the art in elevator technology to an extremely high level.

But still, this level is not high enough to keep pace with the growing demands of high-rise buildings. The main technologies for the next quantum leap are building discipline-independent, and center around digitization. This opens up the potential for BIM, that manages not only the planning phase, but shortens the construction phase and makes a building highly performant, economic and energy efficient over its life time. Further exciting advances in modular construction, and the interconnection of systems and buildings in unprecedented ways, will propel future cities forward.

References:


