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Enhancing Construction Efficiency and Safety with Self-climbing Elevators

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Dennis Murphy has more than three decades of experience in the installation of vertical transportation, process development and implementation. His expertise includes estimating and installation support for major projects with specific focus on high-rise buildings.

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Johannes de Jong M.Sc. Eng. is presently Head of Technology for KONE Major Projects globally.

Due to his exceptionally wide technical expertise he functions as one of the senior vertical transportation advisors globally, and has received several awards and mentions for his work, including the prestigious NOVA award for innovation.

He is a member of the advisory group and a fellow of the CTBUH and a member on several technical workgroups of the European Elevator Code committee.

Johannes holds over 500 different patents and he has also been involved in many of the world's tallest buildings.

Abstract

This paper describes how the use of self-climbing elevators, can significantly improve building construction efficiency.

The self-climbing elevator uses the building's hoist-ways while under construction. The elevator follows the formwork as the building grows, providing greater load capacities and speeds than rack-and-pinion hoists. It operates regardless of weather conditions such as wind, rain, and snow and the building's external profile that may twist, bend and turn.

Self-climbing elevators provide faster, safer, and more reliable elevator service for people and materials throughout construction enabling greater productivity, better quality, and reduced costs. They can shorten construction schedules by as much as 20%, providing greater return on investment.

Shorter schedules and better material flow also provide savings on insurance and storage costs. Because fewer external lifts are required and construction progresses more rapidly, self-climbing elevator helps to reduce the project's overall impact on the surrounding community.

Keywords: Construction cost, construction efficiency, vertical transportation, work safety

Standing Tall

Tall buildings. They are why we are here. They are why most of us get up in the morning and why many of us stay up late into the night. These structures change skylines, sometimes creating them for the very first time. They allow people to work, sleep, be educated and play while never needing a car, train, bus or anything else. They are vertical neighborhoods complete with stores and gardens and so much more. It makes sense, therefore, that so much attention is placed on the innovations that have allowed us to build them taller, make them more efficient, respectful of their surroundings and culture; more environmentally friendly overall. This is great work, and becomes more and more critical all the time. It is the future (see Figure 1).

Unlike the product of our efforts, the effort itself is not something people necessarily care about or want to see, present company excluded. Most of the utilities in the finished buildings

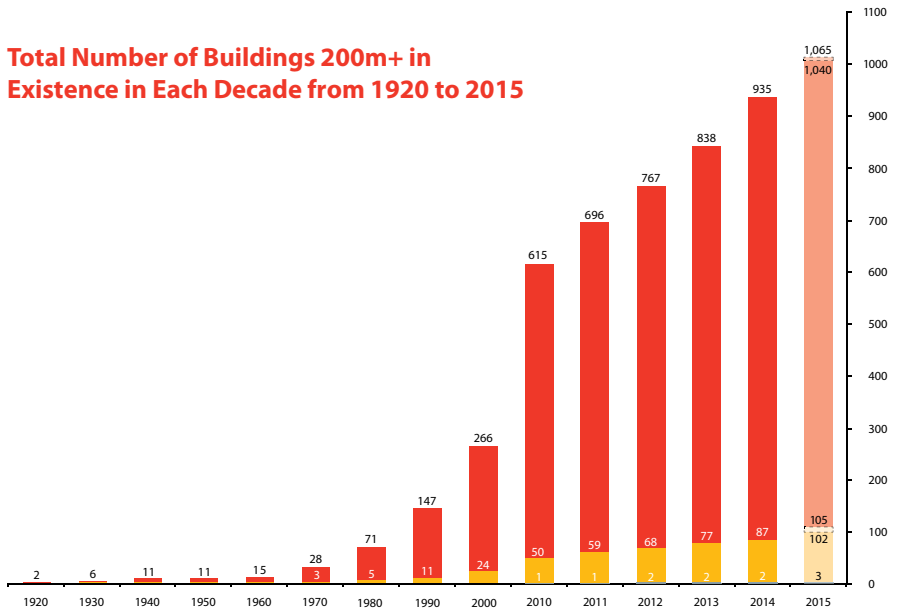

Figure 1. Urbanization and the need for ever taller buildings is an important mega-trend affecting the global elevator and escalator industry and one that is expected to drive demand for years to come (Source: CTBUH)

Jumping Up

The self-climbing construction elevator is an elevator system that uses the permanent entrances, cabs, machines and controllers to move construction workers and their tools throughout the building during construction. It uses the building's permanent hoistways while under construction. The mobile machine room effectively splits each hoistway in two, allowing installation of rails and other shaft materials above the elevator and use of full vertical transportation below (see Figure 3). The self-climbing elevator follows the form work as the building grows, providing greater load capacities and speeds than rack-and-pinion hoists. It operates regardless of weather conditions such as wind, rain and snow, and of the building's external profile that may be subject to twists, bends and turns.

A self-climbing construction elevator provides faster, more reliable elevator service for people and materials throughout construction, enabling greater productivity, better quality and reduced costs. It can shorten construction schedules by as much as 20 percent, delivering greater return on investment. Because these construction elevators are inside and a part of the building's permanent structure, they are also safer. These elevators as a concept are not new. In fact, they have been used in a number of very select cases around the world for the past two decades. What is new is the level of sophistication, scalability and repeatability in today's solution that not only improves the theoretical application rate, but also the level of understanding and acceptance by the governing bodies. This is a critical advancement. To gain wide-spread approval by authorities, these solutions had to be industrialized, documented, and proven. This is the most important distinction between the past and where we are today.

Saving Time

Just like the cities where we build these tremendous towers, buildings under construction can have a massive traffic problem. Once our workforce arrives, they start the second commute of their day, sometimes queuing for hours to get from the street level up to where they left work the day before. As the work day ends, the same thing can occur. While less visible, since the workers are inside the building and distributed across a number of floors, the time spent commuting is no less wasteful than those who may be stuck commuting from suburbs to major metropolitan areas. The total impact on productive time can be crippling. Let's use a simple example to help illustrate the point.

Let's assume there are 500 workers on a project site. On buildings with smaller footprints, the worker population may be slightly less. At the same time, projects like Burj Khalifa and Marina Bay Sands have been estimated to house more than 20,000 workers. On the more typical projects, data shows that workers will spend 1.5 hours to get to their worksite at the beginning of the day; they spend another 1.5 hours to get down when the day is over.

500 workers
x 1.5 hours
x 2 times-a-day, per worker
1,500 hours

Put that in perspective: Every day, 1,500 work hours, or roughly nine work months, are lost moving the labor into and out of a building under construction. Consider the inter-floor traffic throughout the day and the problem gets worse. Regardless of where it is in the world, this is an enormous productivity hit.

There are a number of strategies to deal with this. More external hoists can be installed These are extremely costly, taking up significant and valuable space that is needed for material handling on the ground. Perhaps the most common strategy is staggering the start and end times for a trade or group of trades, to prevent all workers from showing up at the same time. This can lower the burden on the external hoists for the upward and downward peaks. However, there is a problem with this approach. As the later shifts arrive, they're no longer just competing with other workers for space in the personnel hoists; these workers are now competing with the workers who've already arrived and the material they require as the project progresses. This results in continued delays.

Delivering the Solution

A self-climbing construction elevator (SCCE) addresses this issue on multiple fronts. The most obvious is with speed. These elevators travel at up to 800 feet/minute (4 meters/second). This is four-to-six-times faster than the typical external hoist. Even when you allow for potential differences in capacity, an SCCE moves people three-times faster than an external hoist. One of the largest, with capacity of 8,000 pounds (3,629 kilograms), enables a construction site to access the entire speed differential. The efficiency is clearly seen when watching the time required to disperse the morning crowds and the lack of unproductive congregating throughout the

Figure 4. SCCEs flexibility allow them to provide great impact early, and monumental savings over the life of construction (Source: KONE)

Figure 2. Increasingly, property owners and developers must ensure that tenants can move into, through, and out of buildings quickly and comfortably; simultaneously providing improved security and access control (Source: KONE)

are this way. Take HVAC for example. No one wants hot or cold air blowing on them. They want a space that is fresh and comfortable. No one wants to see the fire protection system. They just want to know that it will work when it's needed. For all but the most unique exceptions, vertical transportation is no different. As counterintuitive as it may seem and difficult for us to accept, our greatest praise comes when building occupants barely notice our products. Think about all that we do and the innovations in our market over the last decade. Most have, in one way or another, allowed us to be less visible, not more. That's exactly how it should be. Elevators become an extension of the lobby, with finishes and the user experience flowing freely from one to another. This flow is passed on to the building users, as they pass unimpeded into, through and out of the buildings (see Figure 2). Control systems allow cars to be called automatically, with destination automatically programmed into the machine. And the mechanics of the elevators themselves have changed, enabling less space to be consumed by the equipment, so more is available for the buildings' purposes. Of course, as we continually drive energy efficiency, our tangible impact drops even further. This blending, or transparency, drives so much of what we do; allowing inhabitants to focus completely on what they're doing, rather than on what we do to enable them.

Constructing the Invisible

So what about the actual construction process? It's often viewed as a means to an end – the ribbon cutting, grand opening, or move-in day. A necessary evil to get to what we all know is the future of global urbanization. During this process there is enormous waste. Its creation is seen as inevitable; a part of the process that can be improved slightly through streamlining, but in all likelihood has already been addressed as companies are constantly challenged to do more with less. This is not to suggest we, as an industry, haven't made great progress in controlling those waste streams. We have. Recycling happens on every site. Great care is taken to ensure that the dust, mud, and other by-products from construction isn't spread to the surrounding areas. This is all fantastic work, and should be commended, however, we can do more. There is still a resource that is wasted every day, and impacts every worker, every constructor and every owner. It is our greatest resource. It is the only thing we cannot recreate or recycle. That resource is time.

This paper will address self-climbing construction elevators, a seemingly-simple but significant innovation in the way high rise buildings are constructed that has almost unbelievable impacts on how time is planned and spent at a construction site. Not only does this method save time, it reduces the construction's impact on the surrounding areas, saves money and, because it is significantly safer, it can save lives.

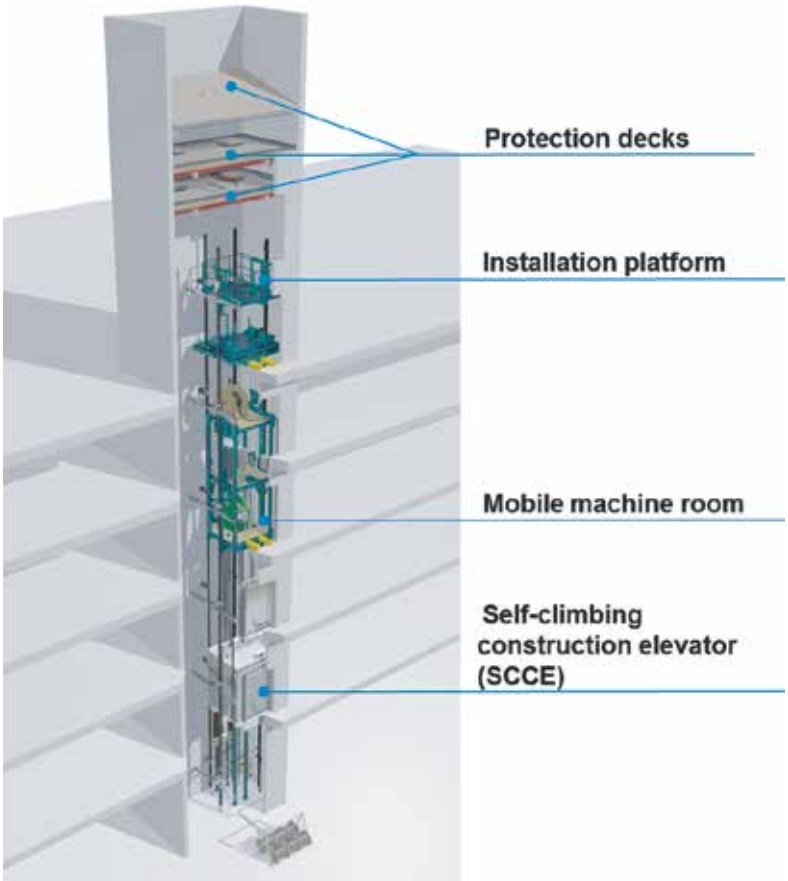

Figure 3. The SCCE provides an engineered solution that is adaptable to almost any high-rise building (Source: KONE)

Figure 5. An external hoist exposes construction workers to the elements and must be shut down in severe weather due to safety concerns (Source: Shutterstock/pryzmat)

Figure 6. Accelerating the building's construction enables earlier opening and faster revenue generation (Source: KONE)

day. If we assume that the SCCE is only twice as fast, the result is the following:

Without SCCE:
500 Workers
x 1.5 Hours
x 2 times-a-day per worker
1,500 hours

With SCCE:
500 Workers
x .75 Hours
x 2 times-a-day per worker
750 hours

Not counting the inter-floor traffic during the workday, a full 750 hours are saved, every day. Let's also assume that out of the twenty-six months the SCCE is available, the worker population averages 500 for 60 percent of the construction time, allowing for ramp up and ramp down. Over the project's life, 546 days of construction, 283,500 hours are saved. That's more than 136 work-years of wasted time avoided (see Figure 4).

The second, and perhaps less obvious improvement offered by these specialized construction elevators is aimed squarely at the challenge of a staggered start for construction workers. It is the fact that workers and material are competing for space. Implementing this vertical transportation solution allows for the separation of the workers from the material. Workers no longer have to compete for the hoist. Material is delivered to the hoist at the bottom floor, and the workers are there to meet it at the top. This process results in far less downtime, since the material is less likely to be damaged by crowding it with other tools, boxes and gear. Since workers aren't riding with the loaded material carts, injuries from cart-to-person collisions are also eliminated.

Dealing with Mother Nature

Regardless of the site's location, weather becomes a factor when building towers. In the most aggressive areas, there is rain, snow, ice, and possibly, sand. All of these things find their way into the hoist's mechanics, creating maintenance and operational challenges (see Figure 5). Even in a location that has no severe weather at all (and this is rare), when buildings get over 50 floors the wind gets strong. In these conditions, many construction sites have their hoists shut down every day due to high wind. After these conditions subside, the hoists must be inspected prior to being put back into service. While out of service, workers are forced to walk up and down stairs within the building. If it happens in the morning, some work can be recovered; in the afternoon, many workers will quit early, knowing their "commute" will take them much longer than normal. Even more productivity is lost.

In addition to being faster, and logistically more efficient, the SCCE is more reliable. There are far fewer moving parts, and the building's structure is more stable than the scaffolding used by external hoists. Most important, the SCCE is inside, and completely protected from the weather, just as the building's final elevators will be. While wind and other conditions may shut down the building crane and external hoists, an SCCE continues to run. As a case in point, a single high-rise building in Canada has experienced weather-driven shutdowns of the external hoists that amount to weeks of lost time. During the same period of time, self-climbing construction elevators on the project have made 170,000 trips with only one service call.

Lowering Construction Costs

Efficiency on a project is important. However, if there is no financial benefit from the efficiency, other benefits are often not enough to drive a change. To understand the financial benefits of SCCE, refer back to the example used before.

Without SCCE:
500 Workers
x 1.5 Hours
x 2 times-a-day per worker
1,500 hours

Figure 7. Safety is paramount on and around the One Bloor construction site on one of Toronto's busiest corners (Source: KONE)

With SCCE:
500 Workers
x .75 Hours
x 2 times-a-day per worker
750 hours

Let's now assume that the average cost of the workers on the site is $50.00.

Without SCCE:
1500 hours
x $50 per hour
$75,000 (U.S.) per day "commuting"

With SCCE:
750 hours
x $50 per hour
$37,500 (U.S.) per day "commuting"

That means at the height of construction, $37,500 (U.S.) per day is saved with self-climbing construction elevators. Over that same 546 days, with the rising and falling construction population, that equates to $14,175,000 (U.S.) in cost avoided due to labor alone. We mentioned that there are often additional hoists placed on projects to help alleviate the queuing. Eliminating these additional hoists also results in savings; sometimes $1 million (U.S.) or more at a typical construction site.

Labor overtime, and other costs associated with expediting construction as the deadline approaches, also adds to the project's final cost. In many situations, five percent of the core subcontract costs are expected. On a sizable high-rise building, that cost could easily top $15 million (U.S.).

The savings mentioned so far are for the construction firms. What about the building owners? Are there direct benefits for them as well? Absolutely! Again, we're taking 283,500 non-productive hours out of the construction schedule. With 500 workers on the site, that's more than three months of schedule compression. The value of the construction interest on a $450 million (U.S.) project for those three months could be more than $3 Million (U.S.). Opening the building earlier means additional cash flow. 1.2 million square feet (111,484 square meters), at $30/foot/year is an additional $3 million/month (U.S.) for the building owner/developer, not to mention reduction in debt service. When combined with the other cost avoidance, the total value quickly approaches 10 percent of the building's total cost (see Figure 6).

Providing Greater Safety

Safety trumps all. There is nothing more important than the safety of construction workers, and for the general public around a construction site (see Figure 7). Despite the great emphasis placed on safety, there have been a number of instances where external hoists have detached from buildings and/or had their support structures buckle. These accidents have resulted in significant property damage and personal injury, even tragic fatalities. As previously discussed, a self-climbing construction elevator is inside a building's hoistways. These elevators have all of the code-required safeties installed and are inspected prior to being put into service. This provides for a construction elevator that has a safety system, and a safety record, that is similar to that of an elevator found in a typical occupied building. To date, KONE's self-climbing construction elevators have more than 100 years of combined operation without a single recorded accident.

Avoiding catastrophe isn't the only way this approach improves safety. Because of their speed and reliability, implementing SCCE on a project creates a de facto separation of the workers and the material during their transport to the work zones. This separation means workers aren't riding with the loaded material carts, and injuries from cart-to-person collisions are eliminated. While rarely life-threatening, these injuries can have a great impact on a worker's livelihood and the project's overall success.

Innovation with Collaboration means Everyone Wins

Implementing these self-climbing elevators during the construction process provides a system that significantly reduces the time, cost and potential for accidents in a high-rise construction project. Unlike many other trade-specific innovations, the benefits are realized by all involved with the construction. The construction workers spend less time standing in queues and more time actually performing their work. Because construction workers can be moved so much more efficiently, builders are often able to reduce the number of external hoists on the building, thereby reducing costs.

The time required to complete the building is absolutely reduced, meaning that some of the finance cost is avoided completely. All of these things combine to provide great benefits for the building owner. Many of these cost reductions are passed on, at least in part, to the owner. The reduced construction schedule means the building is occupied more quickly which, of course, drives more revenue.

The trades, the builder, and the owner – this system is good for all of them, but they are not the only benefactors. There is a positive impact on the community as well. Reducing the number of external hoists can mean fewer closed streets and sidewalks; a common occurrence during urban high-rise construction. This means that auto and foot traffic can move more smoothly and safely during the building process. Self-climbing Construction Elevators are inherently quieter. They have significantly fewer moving parts. Since they are inside the final building structure, any noise that is made gets attenuated by the building itself. Finally, it's the reduction in schedule overall, rather than the reduction of construction costs, that provides the greatest benefit to the surrounding community. No matter how careful we all are, some inconvenience is inevitable. An SCCE-based solution allows for that inconvenience to be reduced by 10 percent or more.

Efficiency, speed, independence from acts of Nature, and greater safety. All of these things work together to get us closer to our target of complete transparency, making our greatest impact, no impact at all.

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