# Analysis of the energy efficiency potential of lifts and escalators

## Introduction

Considering the accelerated development of urban areas and the growth of the number of high-rise buildings and commercial facilities, vertical transport systems, such as lifts and escalators, are becoming indispensable elements of the daily functioning of modern buildings. Although their primary goal is to facilitate movement and enable quick and efficient transportation of people between different levels of the facility, these systems are also a significant source of energy consumption.

- It is estimated that more than 7 billion rides are made every day in buildings around the world.

In a world where energy consumption and environmental protection are at the top of global priorities, increasing the energy efficiency of these systems becomes crucial. Energy-efficient lifts and escalators not only reduce building operating costs, but also help reduce carbon dioxide and other harmful gas emissions. This presentation should give a brief analysis of the technology and strategies that make it possible to achieve more energy efficient operation of lifts and escalators.

- New innovations lead to the introduction of energy-efficient lifts that not only consume less energy, but also produce clean "green" energy.

## Historical context and evolution of vertical transport

Probably in no other segment of urban infrastructure has the change been as visible as in the field of vertical transport.

- The first lifts appeared in the 19th century, and their improvement over the decades enabled the construction of tall buildings and skyscrapers, which became synonymous with modern cities. With the development of technology, lifts have gone from basic, manually operated devices to sophisticated systems with electric motors, built-in safety devices and advanced control systems.

A similar development occurred in the escalator industry.

- The first commercial application at the end of the 19th century, until today, escalators have evolved from simple transport devices to complex systems that can be adapted to the specific needs of users, thus increasing overall energy efficiency.

However, despite this progress, these devices are still threatened by high energy consumption, especially during periods when their use and load are lower. It is therefore necessary to consider how modern advances in technology can further reduce consumption and contribute to sustainability

## Challenges of energy efficiency in lifts and escalators

### 1. Suboptimal working conditions

One of the biggest challenges in achieving energy efficiency in vertical transport is suboptimal system operation.

- Lifts, for example, often work even when the number of users is minimal;
- the escalator works continuously, regardless of how many people are using it at that moment;
- the escalators work at full speed during the entire working time, while the number of users is variable, which creates a significant surplus of consumption
- older lifts and escalators often use technologies that are not optimized for energy efficiency, which further increases their consumption.

### 2. Dependence on the power system and older technologies

Most vertical transport systems still depend on technologies that are not fully optimized for energy efficiency. For example, lifts that use older models of electric motors and mechanical systems to lift passengers are often inefficient because they do not have the ability to regenerate energy. A similar situation can be observed with escalators that use energy-intensive systems for starting and controlling the movement of the stairs.

That is why it is imperative to implement advanced technologies that enable the maximum use of renewable energy sources, reducing the need for power from the external power system.

Traditional, older lifts were designed to prioritize functionality, while energy efficiency was not at the forefront. According to research from 2010,

- lifts older than 15 years consume between 5,000 and 8,000 kWh per year, depending on the intensity of use and the height of the building. Older hydraulic lifts are characterized by a low level of energy efficiency, because they require higher power aggregates to start them;
- modern lifts with gearless drives and without a separate machine room consume from 3,500 to 5,000 kWh per year. This represents energy savings of 40-60%, depending on the number of floors, frequency of use and type of building.
- lifts with regenerative drive and energy-efficient systems reduce energy consumption to less than 2,000 kWh per year.

Therefore, a major advantage of gearless motors is they save about 25 percent more energy than geared motors. Gearless motors also run faster and enjoy greater longevity because they feature higher torque and run at lower RPMs.

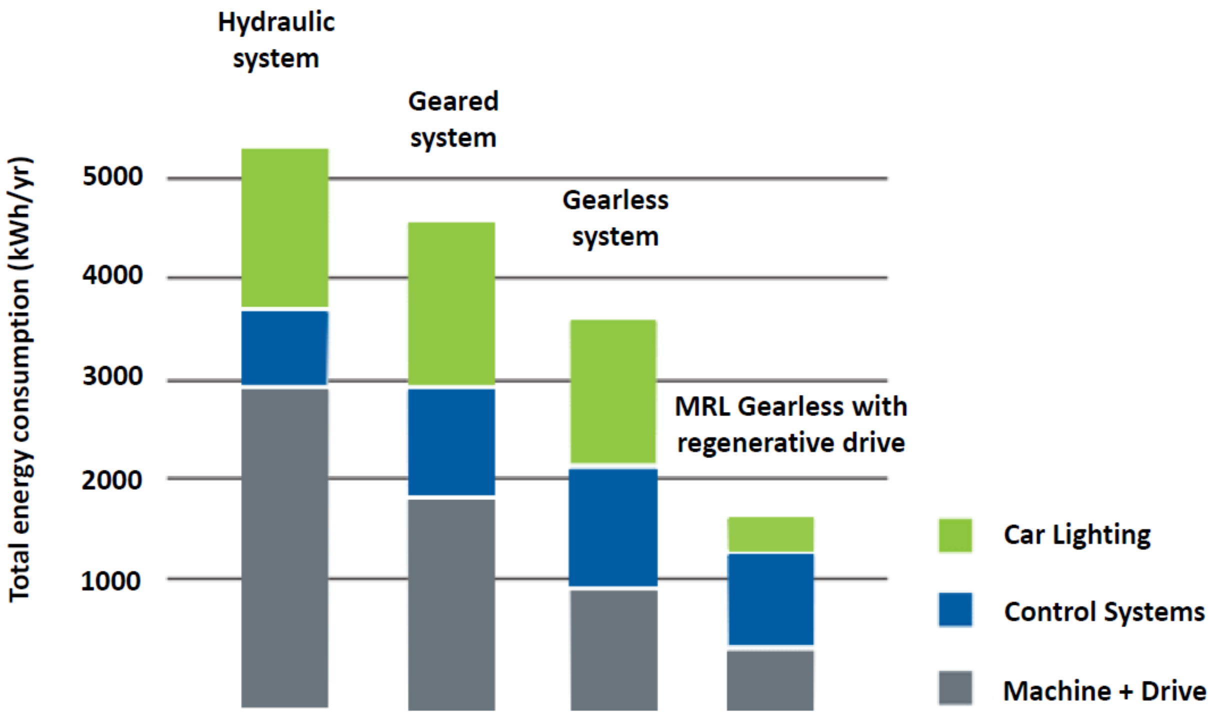


**Figure 1.** A comparison of energy consumptions among different lift systems (Source:http://www.otisworldwide.com)

Much of the “green” agenda focuses on reducing energy consumption.

- Buildings consume about 40% of the world’s energy, and
- lifts account for 2%–10% of a building’s energy consumption,
- During peak usage hours, lifts may utilize up to 40% of the building’s energy

New lifts provide efficiency gains of about 30–40 percent than buildings with older lifts

Quantitative studies on energy consumption of newer and older lift technologies are now being conducted to assess the value of the new technologies. In this regards, ISO 25745-2:2015 standards are used to help to estimate energy consumption.

**Technological innovations in lifts**

**1. Regenerative drive**

One of the most important technologies that can drastically improve the energy efficiency of lifts is regenerative drives. These systems allow the energy generated during lift descent, instead of being lost as heat, to be retained and used for the next lift start. In some cases, this energy can be fed back into the building's power, reducing overall energy consumption.

This drives work by capturing and converting the energy used from braking to maintain the lifts speed. More specifically, traction lifts use a counterweight to balance the weight of the lift car and passengers. The counterweight is sized in an optimal way, approximately to a car loaded to 40%–50% of capacity. Hypothetically, if the counterweight is too heavy or too light, then the lift will overwork the motor and the braking system. When the lift car is loaded less or more than the 50 percent capacity (traveling up cars are light, or traveling down cars are heavy) the lift applies brakes to maintain their rated speed. Braking is provided by allowing the AC motor to operate as a generator, converting mechanical energy to electrical energy which is dissipated as heat by special heat resistors. The regenerative drive captures that energy and channels it back to the building or the city power grid. Saving energy can be done in multiple ways including:

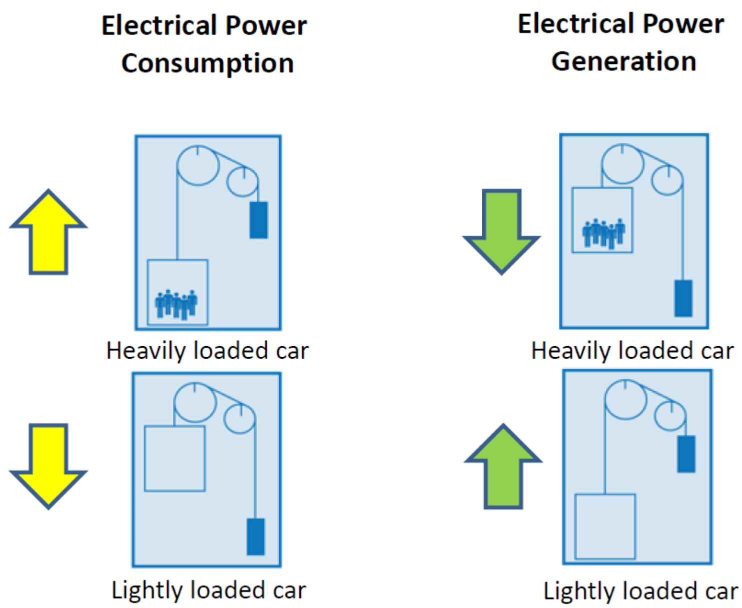


Figure 2 Regenerative lift drive

- When the lift slows down, it applies brakes and energy is created. In a conventional lift system, that energy is dissipated as heat through a heat resister. The regenerative drive harnesses that energy.
- Whenever an empty or lightly loaded lift goes up, the lift applies brakes to maintain the rated speed. As is the case of slowing down, that energy is usually lost but the regenerative drive harnesses it. Further, when an empty or a lightly loaded lift goes up, the motor spins but the lift's counterweight does most of the work. The regenerative drive harnesses that spinning energy by transforming mechanical power into electrical power.
- When a heavy lift goes down, it applies brakes to maintain the desired speed. In a conventional system, the energy created by the braking system is lost. The regenerative drive harnesses that energy. Further, when a heavy lift goes down, the motor spins but gravity does most of the work. The regenerative drive again harnesses that spinning energy by transforming mechanical power into electrical power.

Over time these small amounts of harnessed and saved power on a daily basis add up to significant energy savings.

- Generally, a regenerative drive can reduce energy consumption between 20% and 40%. The ultimate amount of energy savings depends on several variables including: length of trips, frequency and pattern of use, and age of equipment. Overall, the longer the traveled distances and the greater the number of trips result in the greater generated energy.

**Suspension means**

The lift rope is an essential component of traction lifts because it connects the lift engine with the car and counterweight. Conventionally, ropes are made of steel, which is strong enough to hold cabins. However, in supertall and megatall buildings, as these ropes get longer, they get extremely heavy—the rope weight increases exponentially with height. In very tall buildings, ropes may stretch for too long, adding dozens of tons of additional weight that can result in the rope breaking or snapping. In very tall buildings, almost 70% of the lift's weight is attributed to the cable itself, and when the rope gets too long it cannot support its own weight.

Total rope's weight for an lift with a rated load of 2000 kilograms at a travel distance of 500 m can be about 27,000 kg.

In response to these problems, lift companies have been working on improving cable capabilities. For example, companise developed specially designed ropes or belts, which is stronger and lighter than the conventional steel rope. These stronger and lighter ropes require less energy to move and transport lift cabs, leading to significant power savings.

**Double deck and The TWIN System of cars**

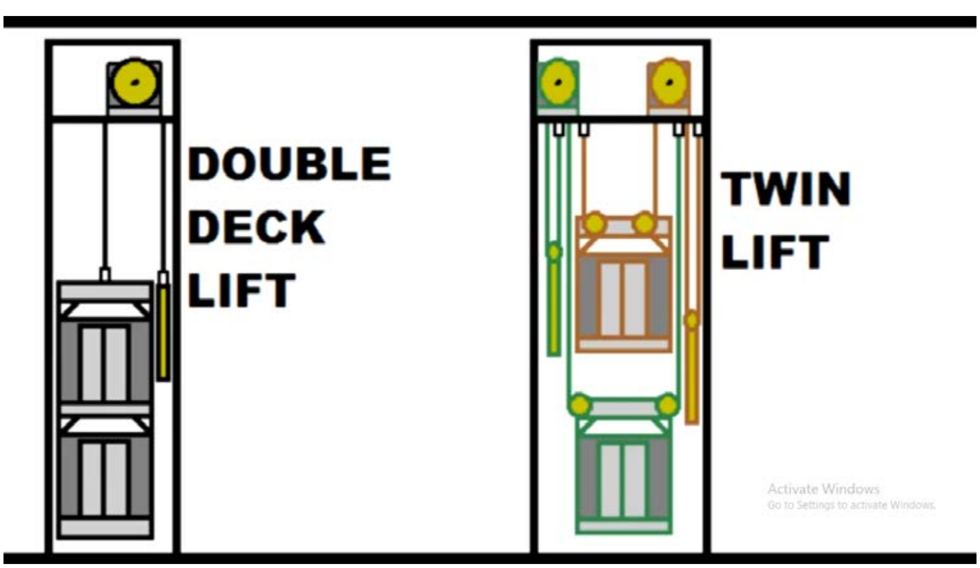


Figure 3 Double deck and The TWIN System of cars

The advantage of the TWIN is that two cabs run independently in a single shaft. The system keeps a safe distance between the two lifts (upper and lower cabins) that are running on top of each other. The TWIN system basically provides savings in space as it cuts the number of shafts needed by one-third, compared to conventional lifts.

In addition to freeing useful space, the TWIN system reduces required building materials for shafts, and hence reduces costs. There is also one control machine for both lifts in the same shaft, leading to additional savings on space and energy. Through a computerized system, it also optimizes the travel of both cabins in assigning the most efficient destinations for passengers, providing efficient service that minimizes wait time and provides fewer stops and empty trips. This leads to additional energy savings.

Double Deck lifts are two cabs tall, where one cab serves even-numbered floors and the other serves odd-numbered floors, resulting in reducing the total number of needed lifts. Double Deck lifts can reduce a building's overall energy usage by reducing the number of stops and even the total number of lifts required when used with destination dispatch controls.

## 2. Destination Dispatching Systems

In a conventional call system, the users push up and down buttons, and lifts answer the call. This system works fine in buildings that have low "vertical ridership" and do not experience "rush hour" traffic. In heavy traffic, lots of buttons are pushed that will result in lots of lift stops, increasing travel and wait time. High speed lift, say with a speed of 6 m per second, each stop may require as much as 10–13 s.

Destination Control Systems (DCS) are a technology that enables improved optimization of lift operation. Passengers pre-select their destination floor before entering the lift, reducing the number of unnecessary stops on floors that are not needed. These systems use advanced algorithms that enable crowd prediction and optimal lift routing, thus increasing system capacity and efficiency.

DCS systems also reduce waiting times and increase the overall speed of lifts, which directly leads to a reduction in overall energy consumption.

DDS provides important benefits including decreasing energy consumption, reducing waiting time, and minimizing crowding and congestion in the building lobbies and hallways. DDS' manufacturers claim that the average traveling time can be reduced by about 30 percent. Average wait time for the lift in a typical 16-floor building with a dispatch system is 13 s, while the average wait time for the lift in the same building with a conventional system is 138 s.

One problem with dispatching systems is that they do not differentiate a group of passengers from a single passenger. This could potentially lead to an lift stopping to pick up more passengers than the lift actually has capacity for, creating delays for other passengers. This situation is handled by two solutions: providing a load vane sensor on the lift or supplying a group function button on the keypad. The load vane tells the lift controller that there is a high load in car and doesn't stop at other floors until the load is low enough to pick up more passengers. The group function button asks for how many passengers are going to a floor, and then the system sends the correct number of lifts to that floor.

- Studies also show that people are more sensitive about waiting times for lifts than any other means of transport, such as buses, trains or boats. A recent survey revealed a maximum lift wait time of 28 s; after that, people started to become restless and show dissatisfaction signs with the lift system.

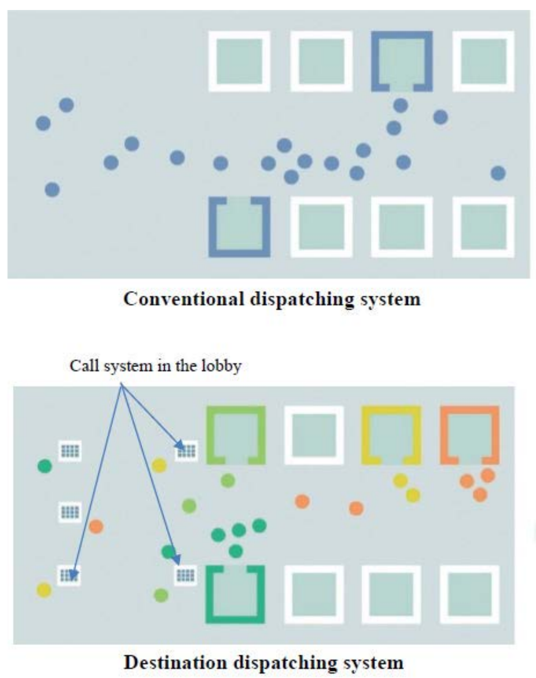


Figure 4 Destination Dispatching Systems

**Standby Solutions**

Standby solutions power down the lift's equipment when it is not in use, providing substantial energy savings, especially in buildings with periods of low lift usage. In-cab sensors and software automatically switch to a "sleep mode," turning off lights, fans, music, and video screens when unoccupied. Energy savings from standby solutions could vary between 25% and 80% of the overall consumption of the lift, depending on multiple variables including the employed control system, lighting type, floor displays and operating consoles in each floor and inside the lift cabin. For example, the lighting feature would greatly factor in the saving formula. Lighting inside the lift cabin can be switched off 40 s after the weight sensor "feels" that there is no one inside.

**3. Use of LED lighting and energy-efficient materials**

Installation of LED lighting in lifts has become standard. LED lights consume significantly less energy compared to traditional light bulbs and have a longer lifespan. In combination with energy-efficient motors and the use of lighter materials for the construction of the cabins, lifts become significantly more efficient and easier to operate, which means less energy consumption for movement. The LED also emits less heat, resulting in less energy needed to cool the cabs. LED lighting is currently used in many new buildings.

**4. Lifts without machine room (MRL)**

Machine roomless lifts are becoming popular due to their compactness and energy efficiency. These systems do not require additional spaces to accommodate the motor and control system, which reduces the total space required for their operation. Also, the use of smaller, more efficient motors reduces energy consumption, and the smaller number of components makes the system easier to maintain.

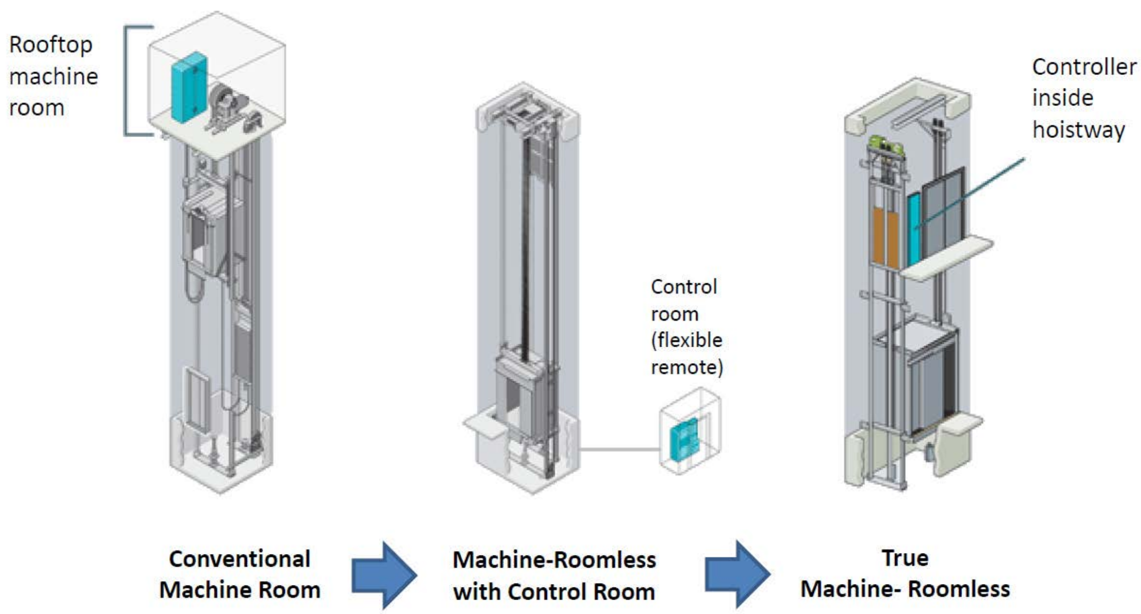


Figure 5 Lifts with and without machine room

**Technological innovations in escalators**

**1. Variable speed**

Variable speed escalators represent one of the most important advances in energy efficiency. The system can automatically adjust the speed of the stairs depending on the number of passengers. When traffic is low, the stairs operate more slowly and use less energy. This is especially useful in large shopping centers or airports, where the number of passengers can vary significantly throughout the day.

**2. Regenerative drive**

Similar to lifts, regenerative drives in escalators can recover energy as passengers descend. This energy can be used to run stairs or fed back into the building's power grid, reducing the need for external power.

**3. Smart sensors and automatic shutdown system**

Advanced motion sensors allow the escalator to operate only when needed. In this way, unnecessary energy consumption is avoided during periods when no activity is present. In combination with automatic shutdown systems when there are no passengers, such systems can reduce energy consumption by more than 50%.

- The average annual energy consumption of standard escalators can be between 10,000 and 15,000 kWh, depending on the height and intensity of use. With the application of variable speeds and motion sensors, energy consumption can be reduced by 20-30%. For example, escalators with advanced systems in the Mall of the Emirates in Dubai reduced energy consumption by 25% after the introduction of these technologies.

**Operational strategies for increasing energy efficiency**

**1. Work optimization**

Proper optimization of the operation of lifts and escalators can significantly reduce their energy consumption. For example, installing a system to automatically turn off lifts and stairs during periods when large numbers of people are not present can reduce unnecessary consumption. In many buildings, this can be achieved by installing devices that automatically adjust system operation depending on daily needs.

**2. Regular service and maintenance**

Regular maintenance of lifts and escalators is key to preserving their energy efficiency. Without regular servicing, many system components can become inefficient, resulting in increased energy consumption. Regularly lubricating parts, checking the system and replacing worn components can extend the life of the system and reduce overall energy costs.

**3. User education**

Building users play a key role in energy efficiency. Education about the rational use of lifts and escalators, as well as promoting the use of stairs instead of lifts for shorter distances, can further reduce energy consumption. In addition, informing users about when it is better to use the lift or escalator can have a positive effect on the overall energy efficiency of the system.

## Conclusion

Considering the increasing demands for energy-efficient solutions in modern buildings, the energy efficiency of lifts and escalators is becoming a key factor in the sustainable development of urban environments. By using advanced technologies such as regenerative drives, smart control systems, LED lighting and energy-efficient motors, vertical transport can become significantly more efficient and environmentally friendly. In addition to technological innovations, the implementation of strategies such as work optimization, regular maintenance and user education can contribute to an even greater reduction in energy consumption. Combined, these practices and technologies represent a path to a more sustainable and energy efficient future.

Green technology extends beyond the lift's operations. For example, cab walls could be composed of 100-percent recycled material. Green lifts can improve building health by avoiding toxic volatile organic compounds (VOC) that pollute indoor air.

In addition, important technological advances have improved lift speeds. In today's fast-paced environment, speedy lifts are needed to move passengers to their destinations in the shortest time possible. They help reduce overcrowding in the buildings' lobbies, sky lobbies, and corridors. Further, the taller a buildings gets, the faster we need lifts to go so as to keep the travel time at an acceptable level. In relatively short buildings the time spent in an lift could be insignificant, but in the case of tall, supertall or megatall buildings, speed becomes essential [17].

- Indeed, advancements in lift speeds have been remarkable. The first commercial passenger lift, installed by Otis Lift Company in 1857, climbed 0.2 m/s
- In comparison, Shanghai Tower's lifts now travel with a speed of 18 m/s. Further, Hitachi is installing new lifts in CTF Finance Center in China, with a speed of 20 m/s
- In a period of about 150 years, lift speed has increased from 0.2 m/s to 20 m/s. This means that the lift speed has increased 100 times—an impressive technological advancement (Table 1).

Figure 6 Left is a photograph of the Otis lift introduced in 1856. It is currently housed in the Gardner's Warehouse in Glasgow, Scotland. Right is a photograph of Mitsubishi lift installed in the recently completed Shanghai Tower in Shanghai, China. Otis lift ran at a speed of about 0.2 m/s, while Mitsubishi runs at a speed of 18 m/s.
(Source: Left, Wikimedia; Right, mitsubishilift.com).

Electromagnetic Levitation Technology, or maglev for short, makes super high-speed trains run frictionless along a track by applying magnetic power. ThyssenKrupp is working on a "multi" system, a rope-free lift system that applies the same concept but on the vertical plane. The "multi" will move multiple cabins vertically and horizontally in a loop. It aims to increase the tube transport capacity by up to 50% with a continuous flow speed of 5 m/s and cabin arrivals every 15–30 s, whilst offering significant space saving because the compartments will be much smaller in size. Current lift and escalator footprints can occupy up to 40% of a building's floor (Figure 7).

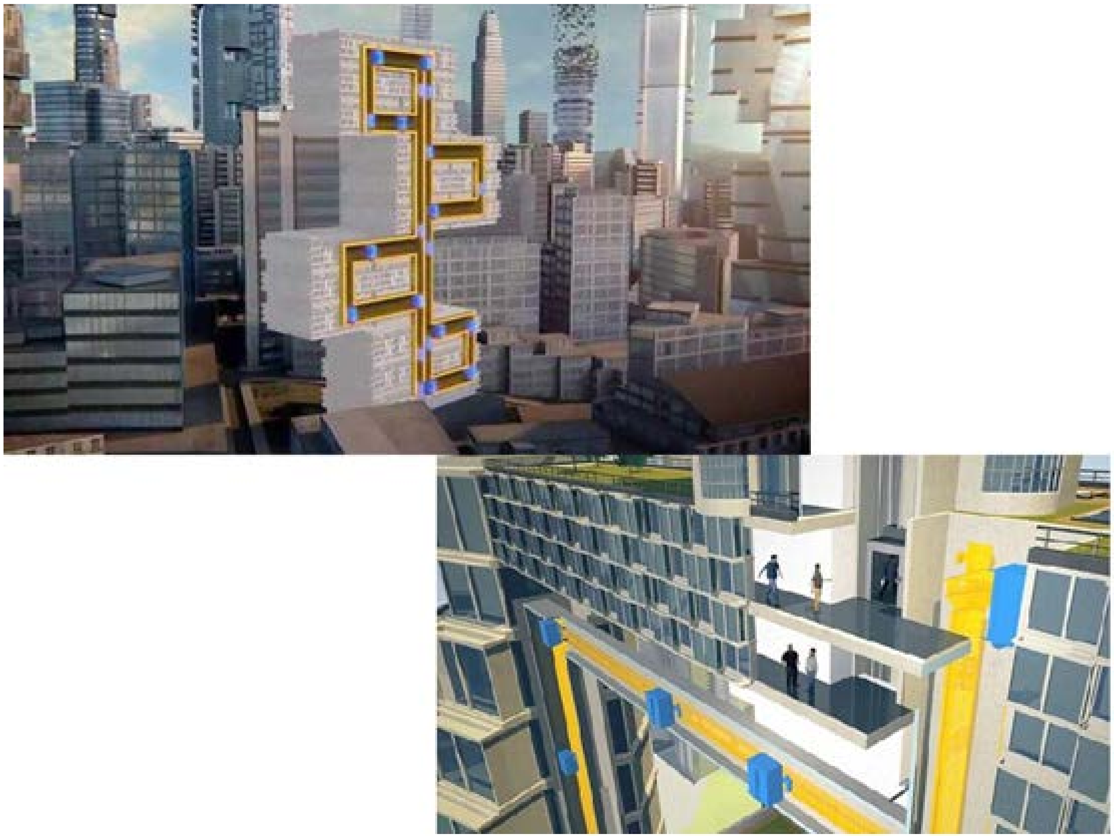

Figure 7 "Multi" drive

Thank You for Your attention!

Božo Vukašinović, MScME
Head of Inspection Body

Elkont Engineering ltd, Belgrade

bozovukasinovic@gmail.com

office@elkont.com
office@elkont.rs