Rick Barker

BARKER MOHANDAS
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Rick Barker is a principal of Barker Mohandas Vertical Transportation Consultants and is involved in most of the firm's work. Prior to co-founding Barker Mohandas, he was the director of technical services at Otis World Headquarters. He also chaired the Otis product strategy group for dispatching control products and simulation tools, and co-led strategy for the company's tall building elevator Skyway™. Mr. Barker led a major study to improve elevator energy efficiency; co-led the Otis Odyssey™ system development, which integrated horizontal and vertical transportation; and was a key liaison between Otis world headquarters and United Technologies Research Center. He previously led vertical transportation at Jaros Baum & Bolles Consulting Engineers. He was involved at Westinghouse Elevator (now Schindler) in the company's largest projects in western New York State, and at Delta Elevator in Boston (now Otis) in the company's largest modernization contracts. The author of multiple professional papers and lecturer at conferences and at two leading universities, Mr. Barker is named, singly or jointly, in 24 patents held by Otis.

里克・巴克, 巴克・莫汉达咨询公司

里克・巴克是巴克・莫汉达垂直运输咨询公司的负责人，并参与了公司的大部分工作。在协同创立巴克・莫汉达咨询公司之前，他曾担任奥的斯世界总部技术服务部门的主管，同时也主持奥的斯产品策略小组，负责协调控制产品和模拟工具，同时协同主导公司高层电梯品牌Skyway™的运营策略。巴克先生对提高电梯能耗做了大量研究，协同领导了奥的斯Odyssey™系列产品的开发——这一产品将水平和垂直运输整合在一起，他同时还是奥的斯世界总部和美国联合技术研究中心之间关键性的联络员。他之前在JB&B工程师事务所负责垂直运输工作，参与了西屋电梯（现在的迅达集团）在纽约州西部最大的项目，以及波士顿的三角洲电梯（现在的奥的斯）公司最大型的现代化合同工程。他是多篇专业论文的作者，并在多个会议以及多所著名大学发表过演讲。巴克先生拥有24项专利，有些是单独持有的，有些是与他人共同持有的。

For complete biography, please refer to Appendix 1.

*有关完整的简历，请参阅附录1。

Dubai, view from the Burj Khalifa during construction (2008)
迪拜，哈利法塔建设期间从上面看的景致

In recent years buildings have soared to unprecedented heights. Is there a limit to how high they can go?

From the perspective of vertical transportation we have found that, even with the components available today, a kilometer [3,280 feet] is not that difficult. We have also done studies for mile-high buildings [1.61 kilometers]. The trick using conventional components is the system strategy, until improvements in elevator or lift technology are developed and available.

Is it safe to say that vertical transportation experts should be consulted early in the design process, even at the conceptual stage?

Exactly right. The sooner the better—basically once an architect has a form, and a general occupancy massing in mind with the Owner. For very tall buildings, we're consulted in parallel with the structural engineer. The taller a building and/or the more mixed use, the first thing you want to know is how to stack up the occupancy and what's the impact on the building core or cores. You want the most dense occupancy at the bottom, so it's usually most efficient to start with commercial and offices; then hotel, sometimes with connected serviced apartments above that; then residential apartments; and then, for perhaps the best revenues, a luxury hotel and, of course, an observation deck on top. There have been times when a client has actually switched the locations of the uses after we've suggested the most efficient stacking of the types of occupancy.

How do sky lobbies come into play?

Sky lobbies naturally separate the types of occupancy in a tall mixed-use tower, and allow some lift hoistways to be located above other lift hoistways in most tall towers. Most of the very tall buildings we see these days are about 100 stories. If that building has mostly offices, it will generally be divided into thirds by two sky lobbies served by shuttle lifts, where passengers will transfer to local lifts. By the way, in any system design, we try to avoid more than two primary lift rides. For example, the tower may have offices in the lower two-thirds and a hotel on top. For the hotel, a guest would take a lift to the sky lobby, check in, and then take a local lift to his or her room. Passengers for the offices may need to ride incidental lifts in the car park, or escalators, but for the luxury hotel, arriving guests will usually be dropped off curbside and can board the sky lobby shuttle lifts directly. For a 100-story apartment tower, a sky lobby is seldom needed.

近年来，建筑在高度上已然飙升到前所未有的水平。对于最大高度，是否有个限制呢？

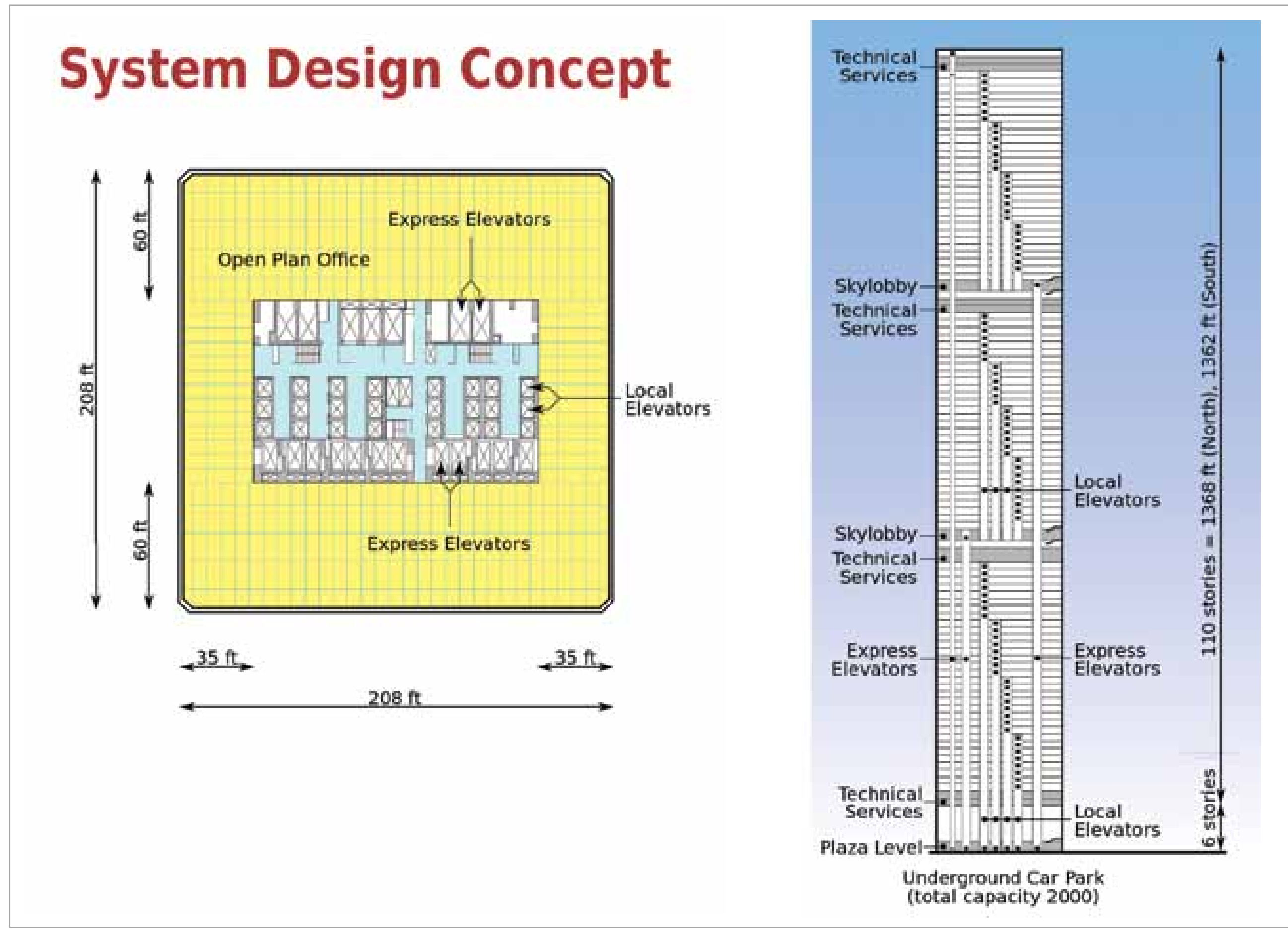
从垂直运输的角度来看，我们发现，就算采用现有的零部件，建设一座一千米（3280英尺）的建筑也并没有那么困难。我们已对一英里高的建筑进行了研究 (1.61公里)。在升降机技术得到改进或升降机进一步发展且付诸实际应用以前，使用传统零部件的方法是最系统性的策略。

能否肯定地说，在设计过程中——甚至是在概念构思阶段，应该早点咨询垂直运输 家？

这绝对是正确的。而且越快越好——基本上，只要建筑师有了雏形，在头脑中有一个大概的业主入住率概念图就可以了。就非常高的建筑而言，向我们咨询和向结构工程师的咨询都是同步进行的。建筑越高，它的用途越多样，你首先要知道如何计算入住率，以及它会对建筑核心有什么影响。人们希望在建筑的底部，让入住率达到最高，所以一般来说在底部以商用、办公室建筑开始是最有效的；然后是宾馆，有时在上面会有连在一起的酒店式公寓；再往上是住宅公寓；然后可能是收益最大的豪华酒店，当然，顶部会有一个观景台。有时，在我们给出最有效使用不同楼层排列布置类型的建议后，客户实际上已经变更了不同使用类型的位置。

空中大堂如何在其中发挥作用？

空中大堂很自然地区分开一栋多重用途高楼中的不同使用类型，它能让一些电梯井道置于另外一些电梯井道之上。今天我们看到的大多数超高层建筑基本上都在一百层左右。如果该建筑的用途主要是办公室，一般来说它会被两个空中大堂分为三部分，穿梭式电梯将会在其中发挥作用，乘客们可以通过它换乘到区域电梯中去。顺便说一下，在任何系统设计中，我们都试图避免两次以上的电梯换乘。例如，高楼在较低的三分之二可能是办公室，而在顶部则是一家宾馆。对于宾馆而言，客人将乘坐一部电梯到达空中大堂，登记入住，然后乘坐一部区域电梯到达自己的房间。要去办公室的客人可能需要使用停车场的附属电梯或自动扶梯；但对于豪华酒店来说，客人到达时一般会停靠在路边，因此可以直接乘坐到达空中大堂的穿梭式电梯。而一栋一百层的公寓楼，则几乎不需要空中大堂。



World Trade Center, New York (1966-73); Elevator System Design Concept
纽约世贸中心（1966年—1973年），电梯系统设计理念

在规划中东一座前所未有的一英里大楼（1.61千米）时，贝建中（Didi Pei）第一次提出了市镇中心的概念来解决这些问题，这种市镇中心不是一个空中大堂，但它根本上是将大堂主体提升到一个使大楼合理的位置，考虑到实际街道层面上的人流量，这个合理的位置是60层。由此，我们当然可以规划出带有空中大堂，又是“传统的”，一千米高（3280英尺高）的大楼，并用一座实际在楼顶之下的观景台对大楼顶部进行修饰装点。再说一遍，利用现有的电梯技术，我们可以做很多事情。

在公寓中，空中大堂可以进一步分开，我们可以用更少的电梯为更多的楼层服务。但是对于办公室来说，根据楼层的区域以及可用于区域电梯的空间大小，会对楼层的多少有一个限制，大约是每

In a plan for an unexecuted mile-high [1.61 kilometer-high] tower in the Middle East, Didi Pei approached the issues by first proposing a town center, not quite a sky lobby, but basically raising the main lobby up to a place that starts to make sense for such a tower, about 60 stories high, considering the mass circulation at the actual street level. From there we could essentially help plan what would be considered a "conventional" 1-kilometer-tall [3,280-foot-tall] building with sky lobbies, and trimming off the top of the tower with an observation deck located well below the actual top of the tower. Again, much can be done with technique, using the lift technologies available at the time.

In apartments, the sky lobbies can be further apart; we can serve many more floors with fewer elevators. But for offices there tends to be a limit of about every 32 or so floors, depending on the floor area, and space available for local lifts. The population here is much greater than in a hotel and much more than in apartments. After planning a lift system to handle the populations quantitatively, we then want to look at queue lengths in the main lobby, and how long people will wait for a lift at any floor; unfortunately, their patience is much shorter than waiting for a subway or bus.

What is the maximum wait time?

In an office building 30 seconds should be the maximum average wait, while some people will wait as long as 90 seconds, and very few people should wait longer, maybe 1 to 2 percent of the calls. For apartments and hotels the average wait can be longer. We do traffic studies for the peak demand rates. An office building, of course, has incoming peaks, lunch peaks, and an evening peak. And even at the start and end of the workday there will be counterflow traffic, and when one company occupies many different floors we will see significant interfloor traffic. With a hotel or apartment it's kind of a two-way early-evening peak. Of course, in international hotels traffic can occur anytime. Regardless, we try to match the lift system to the peak demand rates.

The variables to study are many. Let's consider just a 15-story office building served by one group of passenger lifts. How many people are on each floor? How many, how big, and how fast are the lifts, and how many lifts are there in the group? Then, for high-rise office buildings, the questions become a combinatorial problem: How many groups of lifts are there, which ones address all those questions, and how many floors does each lift group serve? To be productive, we found it necessary to develop advanced optimization software to help answer the questions and identify the potential choices of lift systems. Basic multigroup programs were developed at Otis and Westinghouse over 30 years ago, for example by Dr. Bruce Powell. Earlier still, it appears that the first widely accepted method to calculate lift traffic performance was developed by Bassett Jones, a consulting engineer involved with planning elevators for the Empire State Building. He developed a calculation method to study one group of lifts at a time. For example, he calculated that a low-rise group of lifts should serve the first zone of office floors. Another group of lifts, traveling faster, should run express past those office floors to serve another zone of office floors, and so on up the building, with more groups of lifts. Well, if you kept doing that in a tall building, where all lifts start at the main lobby, you would run out of room. So the sky lobby is a brilliant concept. It allows a building to be divided into packages that are stacked up, one on top of the other.

32层左右。这里的人口要远远超过宾馆，而且比公寓中要多的多。在规划完一个电梯系统解决人口数量的问题后，我们开始想主厅的排队长度问题，以及每一层中的人到底需要花多长时间来等一部电梯；不幸的是，他们的耐心往往比等地铁或公交车要差很多。

最长的等待时间是多少？

在一座办公楼里，平均来说，30秒钟是最大的等待时间，当然，有些人可能会等上90秒，更少的一部分人会等得更久——这可能占到要乘坐电梯人数的1%-2%。公寓和宾馆的平均等待时间要长一些。我们做过关于高峰需求率的人流量调查，一栋办公楼当然会有上班高峰，午饭高峰以及傍晚高峰。甚至在工作日的开始和结束时会有人流的逆流，当一个公司占据不同的楼层时会有人流的合流。而宾馆或公寓只有双向的早晚高峰。当然，在一家国际性宾馆，人流会出现在任何时候。无论如何，我们想让电梯系统满足高峰需求率。

要研究的变量太多。让我们先来考虑一栋由一组客梯服务的十五层办公楼。每一层有多少人？有多少电梯，多大载客量，速度有多快，以及一组里面究竟有多少部电梯？而对于高层办公楼来说，这些问题就成了一个综合性的难题：有多少组电梯，每组电梯为多少层楼服务？为了更有效率，我们发现有必要开发一套高级优化软件，来辅助回答这些问题，并标示出诸种潜在可选择的电梯系统。基本的电梯群控程序三十多年前就在奥的斯公司和西屋电气被开发出来了，例如布鲁斯・鲍尔（Bruce Powell）博士的发明。在往前，巴塞特・琼斯（Bassett Jones）提出了最早被广泛接受的，计算电梯流通运输性能的方法，他是一位顾问工程师，参与了帝国大厦电梯的规划。琼斯开发了一种计算方法，可以一次对一组电梯进行研究。例如，他通过计算得出结论认为，一组低层的电梯应该为办公楼层的第一个区域工作。另一组运行更快的电梯，应该迅速通过这些楼层，为办公楼层中的其它区域工作，以此类推，在大楼的上面部分，将会有更多组的电梯。但如果你在高层建筑一直这么做，那么，你将用光所有的房间，因为那里所有电梯都从主厅出发。因此，空中大堂是一个很聪明的概念。它允许一栋建筑被分为多个部分，它们相互之间层层堆叠起来。

什么时候才引入了空中大堂的概念？

许多人都谈到了这个问题，据我了解，它的第一次重要应用归功于赫伯特泰斯勒的纽约港口管理局（现在是纽约和新泽西港口管理局），我参考了一篇1968年的老文章，上面说的很清楚，他们将它用在纽约的世贸中心上。

电梯的最大速度是多少？

多年前当我还在奥的斯的时候，我被鼓励去写一篇论文，主题恰好就是这个，或者说得更准确些：是所需要的速度。我给那篇文章的标题是："每分钟2000 (610米) 英尺够吗？"三菱已经生产出超高速的单层电梯，速度可以达到12.5米（41英尺）每秒。奥的斯感到自己被迫加入到速度竞赛中，设计出了一种速度为15米（49英尺）每秒的电梯。在台北国际金融中心，东芝/通力的产品达到了16.8米（55英尺）每秒。在上海，三菱刚刚卖了些单层电梯给一栋高楼，其速度达到了18米（59英尺）每秒，也就是3600英尺（1080米）每分钟。它就像是一对法拉利或布加迪呼啸着冲向观景台。这些是非常非常特殊的电梯。对于大多数高层办公楼来说，我们最需要的是速度在10米（33英尺）每秒或2000英尺（600米）每分钟的电梯。要运送如此多的人——数千人——我们在空中大堂的穿梭式电梯和区域电梯中，都采用了双层设计。让这么重的电梯轿厢以更快的速度运行显然是不现实的，因为钢缆的重量、机械设备、电力系统、轿厢结构等等都会非常巨大。当我们有这么多人要运输的时候，小而快速的单层电梯没有太大的帮助。这就是我过去在奥的斯那篇文章的主旨，　当我们确实欣赏有着赛车的工程产品，和观景台所具有的吸引力时，我们还是会发现上述观点是对的。现在，更好的方案可能是提供一种向上过程中的景致，那样的话，你就不希望电梯走得太快了。

是否出现过这样的情况，同一个井道中的两部电梯运行的方向恰好相反，一个向上，一个向下？

有一家电梯公司已经重新采用了这样的想法：一个井道中有两部缆绳牵引电梯，它们沿着同样的路线运动，甚至有时还向着对方的方向运动。和许多人一样，我们相信，即使人们的控制能力已经得到提

When was the sky lobby introduced?

It's been claimed by different people, but from my information, including an old paper dating from early 1968, it seems very clear that credit for its first significant application goes to Herbert Tessler of the Port of New York Authority [now the Port Authority of New York and New Jersey], for the World Trade Center in New York.

What is the maximum elevator speed?

When I was at Otis years back I was encouraged to write a paper on just that issue, or rather, the need for speed. I called it, "Is 2000 feet [610 meters] per minute enough?" Mitsubishi had produced super-speed single-deck lifts 12.5 meters [41 feet] per second. Feeling compelled to join the speed race, Otis designed such a lift for 15 meters [49 feet] per second. In Taipei Financial Center, Toshiba/Kone reached 16.8 meters [55 feet] per second. Mitsubishi just sold some single-deck elevators for a tall building in Shanghai that will reach 18 meters [59 feet] per second, which is almost 3,600 feet [1,080 meters] per minute. It's like having a pair of Ferraris or Bugattis racing up to an observation deck. These are very, very special lifts. For most tall office buildings, the most we need to go is 10 meters [33 feet] per second or 2,000 feet [61 meters] per minute. To move so many people—thousands—we use double decks for both the sky lobby shuttle and local lifts. Moving such heavy lift cars at faster speeds is just not practical; the machinery, power electronics, car structure, etc., would be huge, considering the weight of the wire ropes. And little, fast single-deck elevators don't help us when we have so many people to carry. That was essentially the subject of my old Otis paper, and we still find that true, while we do appreciate the product engineering with the race cars, and some of the attraction for an observation deck. Now, it might be even better to provide a view on the way up, but then you would not want to go so fast.

Has there ever been a case where two elevators go up and down in the same shaft?

One elevator company has resurrected the idea of two roped elevators in one hoistway, which are traveling along the same path, and are even traveling toward each other. We believe, as many others do, that this is being done with increased risk, even though controls have improved. The risk is obviously that the cars could crash into each other, which is what happened when Westinghouse Electric tried this in the 1930s. After that it was written out of the elevator code in the U.S. For very tall

Representative double elevator (at Midland Square, Nagoya)
双层电梯的代表
（米德兰广场，名古屋）

buildings, controlling movements of elevator ropes is more difficult, which adds control complications to this old idea.

When I was at Otis, I was very involved in a different idea. The company sought to provide elevator products in the short term suited to the "mile-high" [1.61 kilometer-high] building. Ropeless elevators were not viewed as a short-term product development, so the Otis answer was to "climb the mountain," so to speak, traveling in steps, and using mostly predeveloped parts from their roped elevator product for tall buildings.

For such buildings the basic idea was that the cabs could be moved off the car frame of an elevator, onto the car frame

高，但要做到这些也要冒着不断增加的风险。最明显的风险是：不同的轿厢有可能相互碰撞——上世纪三十年代西屋电器公司在做试验时曾经发生过此类事故。在那之后，美国的电梯规则就禁止了这种方案。对于更高的建筑来说，控制电梯缆绳的运动要困难的多，这就给这一古老的想法增加了控制上的复杂性。

在奥的斯的时候，我被另外一种观点深深吸引。公司想要在短期之内提供适合"一英里高"(1.61公里) 建筑的电梯产品。而无缆电梯并不被看作是一项短期的产品研发，所以奥的斯的回答

是，要"爬山"，也就是说，一步一步前进，最大限度地利用他们为高层建筑生产缆绳电梯时那些前期开发的零件。

对于这些建筑，轿厢可以从一部电梯的结构中分离出来，然后放到一部相连电梯的轿厢结构中去，这将会把轿厢运输到更高的位置上去。当一个轿厢被从电梯的结构中分离出来，另一个轿厢会移动上来，它或者来自一个未连接的装载区，或者来自另一个电梯的轿厢结构，因此考虑到平衡力位于缆绳的另一端，一个缆绳电梯中的机械牵引机制并没有失去其牵引力。用简单的话说，这意味着当人们想要去更高的楼层时，并不需要在空中大堂停下来，从电梯组的这边换到另一边；相反轿厢会让电梯内的乘客一直处于变换的电梯之中，这被称为奥的斯的奥德修斯系统。它不同于当前重新流行的"一个井道两个缆绳电梯"方案，因为电梯绝不会在同一条垂直轨道上运动。它们只在井道中连接的分支管道上相遇。人们可能会说，这一系统采用的是"一个井道多部轿厢"方案，但实际情况与此非常不同。

坦率的说，我并不认为这是为高层建筑给出的最佳方案，但我也确实看到，如果轿厢被从低层电梯的轿厢结构中移出，放到水平的自动载人系统（APMs）中去，其中有一些非常关键的原理对于大型机场以及类似的"宽大直立型"项目非常适用。一位麻省理工学院的教授要求我向他建筑学专业的学生阐述一下奥的斯的奥德维修系统，然后帮他管理一个工作室，以便将这一系统应用在水平载人装置上，这一装置广泛应用于麻省理工学院中斜长的隆起地带。所有这些优点都被预见到了，当然，一个挑战也同样被预见到了，但这是一个很容易满足的挑战，它就是水平系统的灵活性问题，因为这个系统往往非常固定。所有东西上面都有一条缆绳，即使是在水平载人系统上。在地上，对灵活性来说，没有固定住的轿厢是合理的。而这又回到了不能将你自己固定在空中的问题。

无缆绳的悬浮电梯前景如何?

我希望我年轻一些而且有更多的钱。大概在13或14年前，我就投入到无缆绳电梯的研究工作中，尽管不像参加奥德修斯系统那样投入许多的精力。在看到最后的研究成果时，我以为无缆绳电梯是没有希望的。不过当时的研究是电动机和其它相关技术的产物，而且奠基在那时的系统技术研究之上。

of a connecting elevator that would transport the cab even higher. When one cab was moved off a car frame, another would be moved on, from either an offline loading area or from another car frame, so traction was not lost at machine sheave with a roped elevator, considering that the counterweight is attached to the other end of the ropes. What this meant in simple terms was that people wouldn't have to stop at a sky lobby to change from one bank of elevators to another to reach higher floors; rather, the cab would keep changing elevators with the passengers inside. It was called the Otis Odyssey system. It was different from the current resurrection of two roped elevators in one hoistway, because the elevators never traveled in the same vertical path. They only met at connecting offsets in the hoistways. While one might say the system used a single hoistway with multiple cabs, there were significant differences.

Frankly, I didn't think it was the best answer for a tall building, but I did see that if cabs were moved from car frames of low-rise elevators to horizontal automated people movers (APMs), some key elements were very applicable for large airports and similar "wide-rise" projects. A professor at MIT asked me to present Otis Odyssey to his architectural students, and then help him conduct a workshop applying the system, with a horizontal people mover, to the long campus spine of MIT. All kinds of merits were foreseen. One challenge was also foreseen but one that could be easily met. This was the flexibility of the horizontal system, which was quite tethered. Everything had a rope on it, even the horizontal people movers. Untethering cabs on the ground only makes sense for flexibility. This comes back to untethering yourself in the air, as well.

What are the prospects for ropeless maglev elevators?

Well, I wish I were younger and had more money. About 13 or 14 years ago I was involved in a research study on ropeless elevators, although not as involved as with the Odyssey system. After seeing the final study, I thought ropeless is hopeless. However, the study was a product of the motor and other technologies at the time, and was based on the system techniques studied at that time.

For larger applications people back then thought of linear induction motors, which are all wound electrically and have certain inefficiencies as a result. With the introduction of permanent magnets to all kinds of motors, efficiencies have improved, as have flexibilities in arranging and locating motor parts. The introduction of synchronous permanent magnet motors for elevators has been a significant change.

For ropeless elevators, they would be called linear synchronous motors. Included in a second set of changes, which our industry has been slow to pick up on, are lightweight materials. The biggest problem with today's roped elevators is the weight of all its steel ropes—that's our limiting factor.

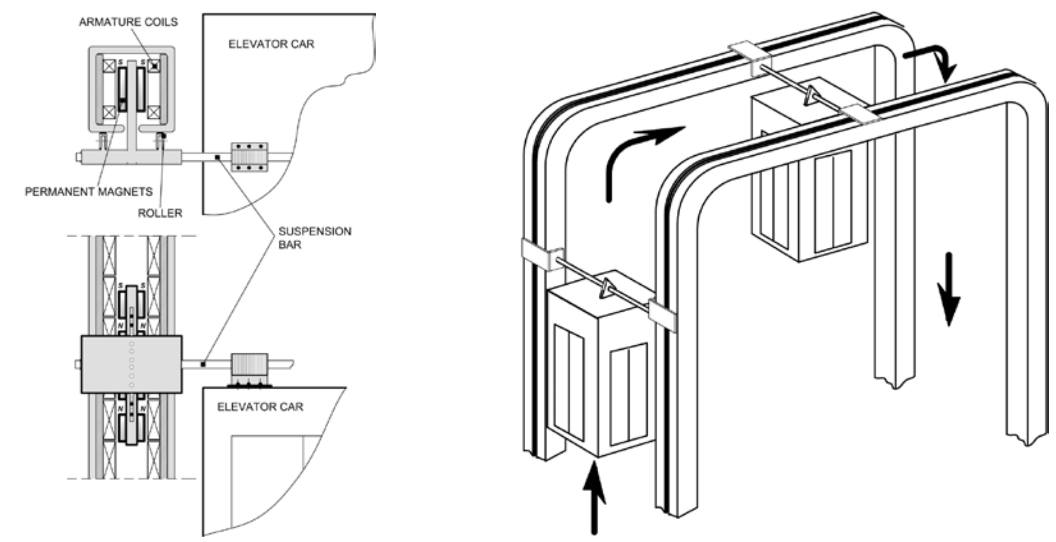
We rely on a counterweight attached to the other end of the ropes so the motor does not have to lift the entire weight of the car and the people inside. And we also have a reverse loop of compensation ropes attached below the counterweight and elevator car to counterbalance the weight of the ropes themselves. Considering the weight of all those steel ropes, the weight of the car frame must increase, along with the capacity of safety devices on the car to stop the car. Control complications also increase significantly with travel with roped elevators. So, if you untether the elevator, car weight naturally decreases, and then you can focus on lightweight materials used in the structure of the car frame. While you will not have the benefit of a counterweight to defy gravity going up, the elevator linear motor and its power electronics drives can be used going down to regenerate power, with untethered elevator cars.

Second in significance are lightweight materials, improvements in noncontact and wireless means to bring power and signals to elevator cars, and some other things. Third, and not necessarily last, is just being smart about the technique or system. If, for example, you had built a ropeless elevator that starts at the ground and then stops at every floor, you would have to wait a long time for it to come back down. You would need more and more elevators, eating up space. You have to employ a smarter technique. For example, if you want to put out a fire at the top of a hill and you run up with one bucket of water at a time, you would have a tough time putting the fire out. But if you keep passing buckets of water to your friends next to you, there is a much higher through-put capacity of water. That was one basic technique in the Otis Odyssey system, to pass cabs on to connecting elevators, to be able to return in less time in the important first leg of the elevator journey.

I believe we have and know the right people to plan, design, test, and build an ideal system. Back when the Dubai market was very hot, we thought we would have somebody to fund this who was also a self-interested investor in tall buildings. Since the major elevator companies find more than 90 percent of their business in low, mid-rise and high-rise buildings, not tall buildings per se, the major elevator companies don't tend to focus much of their R&D on this, primarily because almost everything has to be developed new. You

为了有更大的应用，人们回过头反思直线感应电动机，它在电力应用上完全是个缺陷，最终的结果就是导致某种低效率。随着永久磁铁被引入到各种电动机中，效率得到了提高，而且在排列和安置电动机零件时也具有了灵活性。为电梯引入永磁同步电动机，产生了重大的改变。对于无缆绳电梯，它们将被称为直线同步电动机。第二组改变中所包括的是更轻的材料　——我们的工业已经放慢脚步来了解这种改变了。今天缆绳电梯的最大问题，就是所有这些钢缆的重量——这是限制我们的一个因素。我们现在靠的是系于缆绳另一端的平衡力，因而电动机就不需要举起全部的重量——包括轿厢本身和里面的乘客。在平衡力和电梯轿厢的下方，我们还有补偿性缆绳构成的反向循环系统，以便抵消缆绳自身的重量。考虑到所有这些钢缆的重量，轿厢结构的重量必须要增加，而且轿厢上安全装置的性能也要提高，以便能够在需要的时候让轿厢停下。沿着缆绳电梯运动，控制的复杂性显著提升。所以，如果你切断缆绳和电梯的连结，轿厢的重量自然就降低了，然后你就可以把重点放在轿厢框架结构中的轻质材料上。当你不能够利用一种平衡力来抵消上升所产生的重力时，电梯的直线电机及其电力驱动装置，可以与松开的电梯轿厢一起向下运动以重新产生电能。第二个重要意义在于轻质材料，无接触、无缆绳方法上的进步，它为电梯轿厢带来了电力和电讯号，以及其它一些东西。第三点是——这可能不是最后的一点——技术或系统正变得越来越灵巧高效。例如，如果你已经完成了一部无缆绳电梯，它从地面开始，在每一层都停一下，那么，你要花上很长一段时间等它再次下来。你将需要越来越多的电梯，它们会把空间都消耗占用掉，所以必须采用一种更灵活的技术。例如，如果你要在山顶扑灭大火，而你一次只能带着一桶水跑上去，那么想把火彻底扑灭可能时间上就很成问题。但是如果你不停地将一桶桶水传递到你旁边的朋友手里，那么水的流通输送效率将会高得多。这就是奥的斯的奥德修斯系统中一项最根本的技术，将轿厢传递到邻近连结的电梯中去，这能够让电梯在重要的第一次往返中以最短的时间回来。

我相信我们已经拥有了合适的人选，他们了解如何去规划、设计、测试和建立一个理想系统。在迪拜市场非常火爆的时候，我们认为应该让一些人在这个项目上进行投资——他们同时也是在高层建筑上顾及自身利益的投资者。由于主要的电梯企业



Ropeless elevator, courtesy of Zbigniew Piech, Linear Synchronous Motors – Transportation and Automation Systems, 2nd ed. (2011), Fig. 7.7, Chapter 7, p. 230.

无缆绳电梯，兹比格纽·皮耶希，《直线同步电动机——传输和自动化系统》，第二版，2011年，第七章，第230页，图7.7。

意识到，它们超过90%的生意都在中低层以及高层楼房上，而并非主要集中于超高层建筑，因此，大型的电梯企业并不倾向于过多地将研发精力放在高层建筑上，因为几乎所有东西都需要重新开发。除了规则和安全性，以及你从缆绳电梯的问题中吸取的教训，你几乎要抹去你知道的，关于传统电梯产品的一切。就安全性而言，你想要让无缆绳电梯至少与缆绳电梯相当，甚至从理论上说应当更好。对于许多人来说，如果没有关于安全性的行业知识，这就完全是一种全新的局面。就我而言，我希望在我们变老之前，能够对此项工作贡献绵力。

目前来看，使用细缆绳和现成零部件，电梯可以走到多高的地方？

我们实际上不需要细缆绳，当谈到钢索时，我们需要的是更大的缆绳。这是我们的一个问题。最大的向上距离大约是600米（1968英尺）左右；如果是双层电梯的话，还要短一点，接近于500米（1640英尺）。不过，为了真正回答你的问题，为了克服缆绳电梯中的这一独特障碍，即：缆绳重量问题，几乎所有的电梯制造商都研究且试验了采用芳纶纤维的轻质缆绳，他们获得了不同程度的成效，但也发现了一些重大的问题。似乎到目前为止，我们尚

have to almost erase everything you know about traditional elevator products themselves, except the codes and safety, and also your lessons learned from problems with roped elevators. For safety, you then want the ropeless elevator to be at least equal, and ideally better. Except for that industry knowledge on safety, it is to many people a whole new ball game. For us, I just hope we can contribute to this effort before we all get much older.

At the moment, using thin rope and available components, how high can elevators go?

We actually don't need thin ropes; we need larger ropes when we are talking about steel wire ropes. That's one of our problems. The upward maximum is around 600 or so meters [1,968 feet]; less for a double-deck elevator, where we may see close to 500 meters [1,640 feet] soon. However, to answer your real question, to overcome this particular problem with roped elevators, which is the rope weight, almost all lift manufacturers have researched and tried lightweight ropes using aramid fibers, with varying success and some significant problems. It appears that we have not heard the last word on this yet. However, even if the latest attempt proves successful, all we will have done is to extend travel for a single lift in a hoistway, and again, the higher you go with a single elevator, the longer you need wait for it to come back.

Is there a vertical transportation system for the automatic delivery of goods in a high- rise building?

For our 1-kilometer [3,280-foot] and mile-high [5,280-foot or 1.61 kilometer] towers planned for Dubai, we proposed a unique system of "sky docks," Copyrighted© by Barker Mohandas, LLC, USA, located at or near mechanical levels or sky lobbies, served by express service shuttle elevators. At the "sky docks," the service shuttles connect to local service elevators. If Mrs. Smith wants to move in, she can't just send up her lamp or chair. It just wouldn't work; things need to be in containers and on wheels, prepackaged for productive transport. So we had a system where all the containers were checked through security, tagged, and then automated so that the containers would be loaded on automated bogies, which then carried the containers to the service shuttle elevators, using RFID-based guide paths. The service shuttles then made just one or two stops to the "sky dock" goods lobbies, where the containers were unloaded and goods transferred to the local service lifts. So within your residential zone of maybe 25 floors you would come up or down to get your mail, and so forth. The system was semi-automated to allow staff also to be transported. It's just a matter of cost to go to the next step for fully automated deliveries. We were just providing the main vein for an automated container transport system that we also suggested based on products readily available now. From the sky docks, goods could in fact be transferred onto local lifts and delivered to your door on automated wheeled carts, and with enough sensors the system could also be designed to be staff-friendly.

Tall buildings involve long elevator rides. Are there limits to the amount of time people willingly spend in transit? How is that time best spent?

Our observation is that people do have limits on transit time, particularly in an elevator stopping at every floor. But if you're traveling express or nonstop, it's more tolerable. You know where you are going, you keep moving, it's comfortable. The provision of some key information would enhance the experience. I'm not sure about random audio-visual shows and that kind of thing, which could be more of a distraction, but information about where you are and what is going on, with graphics that can be quickly understood. I think way-finding in these buildings is a very important subject.

Getting around in big buildings isn't always easy. Things don't necessarily align easily when you transfer between elevators, or from elevator to stairs, or move from one area

未听到关于这个问题的最终结论。不过，即使最终的目标被证明已经实现，我们必须要去做的还是延伸一个井道中单部电梯的运行长度，不过，问题又回来了：一部电梯上升的越高，你就需要花费越多的时间等待它回来。

在高层建筑中，有没有一个垂直运输系统，用于货物的自动运送？

为了我们在迪拜规划的，高达1公里（3280英尺）和1英里（5280英尺　或1.61公里）的大楼，我们提出了一套独特的“空中码头”系统（美国巴克莫罕达斯有限责任公司专利所有），它位于或接近于机械层或空中大堂，配备快速的服务梭型电梯。在“空中码头”，服务梭型电梯与局部服务电梯连接在一起。如果史密斯夫人想要搬进来，她就不能仅仅是把她的灯或者椅子运上去，那是没用的。为了有效的运输，必须早就有些东西被完整地安置在轿厢中或在轮子上。所以我们就有了这么一个系统，其中所有的轿厢都通过安全检测，被打上标记且自动运行，因此，轿厢将被装载在自动转向架上，然后利用基于无限射频技术的引导路径，被带到服务梭型电梯中去。然后，服务梭型电梯在到达充斥着货厅的“空中码头”前，只会停一两次；而在“空中码头”中，轿厢中的货物被卸下来，然后换乘到局部服务电梯中去。所以，在你的住宅区内（这个住宅区可能有25层之多），你只需要向上或向下来收取你的邮件等东西。这一系统过去是半自动化的，因而也可运输人员，进入到下一步的全自动化运输，只是一个费用问题。我们只是为一个自动轿厢运输系统提供主干结构，我们也建议说，这一系统应当尽量采用当前可以获得的一些产品。从空中码头出发，货物实际上可以被运输到区域电梯中，然后通过滚动的小车投递上门，如果有了足够的传感器，这个系统也可以被设计成供人使用的。

高层建筑包括很长的电梯运程。就人们能接受的，花在运输上的时间总量而言，有没有一些限制？这个时间应该如何安排利用？

就我们的观察，在运输时间的花费上确实有一定的限度，特别是在一部每层都停的电梯上。但如果你乘坐的是快速或不停顿的电梯，那反倒好得多。你知道要去哪里，你一直在移动，这是很舒畅的。提供一些关键的信息会提升这种经验。我对于随机视

听展示，以及相关类型的东西（它们更多的可能只是用来分散人的注意力）有何作用并不确定，但例如“你在哪里”以及“将会发生什么”这类信息配上图像以后，将会很容易被人们理解。我认为在此类建筑中，路劲查找是一个非常重要的课题。

在一栋大楼里四处走动并不总是很容易的事。当你在电梯之间换乘，或者从电梯走到楼梯，又或者从一个区域到另一个区域时，有些东西并非一定就是井井有条的。也许你对于主厅楼层中的那些双层电梯尚未熟悉。准确清晰的信息需要在第一时间，并且持续的向人们提供。我认为工业设计师和建筑师需要在路径查找方面扮演更为重要的角色。而且，当发生紧急情况时，人们知道该做什么，这也是非常关键的。他们该去哪里？他们如何出去？有一些标示会在你进入大楼进行路径查找时，一直引导着你，同样的，必须有一些标示能够帮助你在紧急情况下逃离大楼。

目标调度有何重要性？

它已经在办公大楼的主厅中找到了自己的位置。它会那些想去普通楼层的乘客安排到特定的电梯轿厢中，因此在上升过程中，电梯停靠的次数就会减少。往返主厅次数上的改进，有助于减少早高峰时段等候的队列。从另一个角度看，电梯作为一套轿厢调度系统，当它与一套安全栅门系统融合在一起时，这项技术也是非常有用的。每次是一个人，而不是一群人冲进来，当然，电子身份卡也会使管理和控制一栋大楼中的人员更加容易。在因火灾需要疏散人员时，或许其中有些人是残疾人、幼童、老者时，至少应当有一些信息能够说明谁还在大楼里，以及他们可能在哪个位置。这是一套真的需要改进和应用的系统，当然，它同时还是要尊重个人的隐私。

关于这一点，美国的规则在消防员自身的消防安全方面已经落在了后面。数十年来，英国都有消防队专用的安全电梯，它也保护了通向楼梯的后备方案。不幸的是，它非常小，只能容纳一辆轮椅或一位装备齐整的消防员。相反，美国只是将每部电梯的钥匙给消防员，而这些电梯并未受到保护。这有点像在一个烟囱里上下移动，特别是规则规定，烟的出口只能在烟囱的顶部。1995年，我曾写过一篇论文，推动为消防员设立安全电梯的主张，我建议使用办公楼中的服务电梯，因为这些电梯很

to another. Or maybe you're not already familiar with double-deck elevators at the main lobby levels. Good, clear information needs to be provided initially, and needs to be ongoing. I think that industrial designers and architects need to play a much, much stronger role in way-finding. Also, it's critical in an emergency that people know what to do. Where should they go? How do they get out? The same displays for way-finding to get in, and that guide you along your way, should be the same displays to help you exit in an emergency.

What is the importance of destination dispatching?

It's already found its place at the main lobby in office buildings, assigning arriving passengers with common floor destinations to certain elevator cabs, so that the number of elevator stops is reduced going up. The improvement in round-trip times from the main lobby helps reduce queues there during the morning peak time. The technique also has benefit when integrated with a security turnstile system that is also in view of the elevators as car assignments are given. It's one person at a time, not a crowd rushing in. Electronic ID cards, of course, also make it easy to manage and control who is in a building. During evacuation for a fire emergency, and/or when disabled, very young, or elderly people are involved, at least there would be some information about who is still in the building and where they might be. It's a system that really needs to evolve and be adopted, while still respecting personal privacy.

On that note, American codes had been lagging behind in fire safety for firefighters. For decades the British have had a protected lift for fire brigade use that also has protected backup access to stairs. Unfortunately, it was very small, capable of accommodating just one wheelchair or a fully-outfitted firefighter. Americans, by contrast, just handed the firefighter keys to every elevator, which were not protected. It's kind of like riding in a chimney, especially since a smoke vent was specified at the top under the code. Back in 1995 I wrote a paper to push the idea of protected elevators for firefighters, recommending the use of service elevators in office buildings, since these elevators are already large enough for an ambulance stretcher. New U.S. model building codes have finally caught up with that and require a protected "first responder's elevator" or "fire service access elevator." And very recently, thanks to encouragement by NIST (National Institute of Standards and Technology, USA), at least for high-rise office buildings, we now need either space for 3 stairways, which is hard to accommodate, or 2 stairways, with the passenger lifts protected for occupant evacuation. So the

U.S. has finally leaped ahead in the codes via the 2009 and later editions of the IBC (International Building Code, USA). When the U.S. makes a statement like that, particularly when we're doing so much international work, it establishes an important model. In our designs we now need to look for protected backup access to stairs from every lift lobby, in case either the elevators or their power fails, or considering that human behavior during a fire may be unpredictable. I would say that as China is thinking about super-tall buildings this needs to be addressed, and the precedent has just been set in the United States.

Is the firefighter's lift lobby smoke free?

It should be, with doors that close during a fire, and with lobbies that are smoke pressurized. Protected backup access to stairs should also be provided in case the lift shuts down or loses power, or simply to allow careful firefighters to ascend the remaining handful of floors to the actual fire floor, using stairs.

But the shaft itself could never be pressurized?

We defer for the wisdom and requirements for that to qualified MEP and fire protection engineers, in conjunction with code authorities, considering also complications with stack effect and reverse stack effect, which becomes a challenge in very tall buildings. While British-based codes may suggest you do this, I think they were initially written for low- to medium-rise buildings in London, and the practicality and effectiveness should be revisited as we build much higher. Under U.S. codes, for example, I think if you protect and pressurize the lift lobbies, there isn't really a need to go further; it would be too late. The pressurized lobby is your first and most important line of defense. Again, we defer further comment to the disciplines mentioned.

Are lift systems sustainable?

I think today, for elevators with wire ropes, the lifts are about as energy efficient as they could be. The motors have become as efficient as they can be for the latest technology available, using permanent magnets that have been introduced to the rotating element in the motor; which has added 3 percent to 5 percent efficiency to the motor component itself. Today's fully regenerative powered electronics drives, which have a power factor close to unity, are another contributor. As an interesting example, during a fire, for lifts operating in evacuation mode, when a lift with a full load goes down, the car is heavier than

大，足够容纳救护车担架。新的美国标准建筑规则最终也迎头赶上，要求一部安全的，“最先可以做出反应的电梯”或者“可用于消防服务的电梯”。最近，多亏了美国国家标准与技术协会（NIST）的推动，至少就高层办公楼而言，我们现在要求，要么有三个楼梯的空间（这一点很难得到满足），要么有两个楼梯的空间，同时客梯必须得到保护以保证疏散时能够容纳人员。因此，通过2009年以及美国国际建筑规则后来的一些版本，美国终于跃升到了前排位置。当美国做出类似的声明，特别是当我们做如此多的国际性工作时，它就确立了一个重要的标准。为了防止电梯或者电梯的电源系统不能工作，或者考虑到人在火灾时的行为是难以预测的，在我们的设计中，现在需要寻找从每个大堂的电梯安全向楼梯撤退的方法。我要说，随着中国正在考虑超高建筑方面的问题，这些需要被提出来，而美国刚刚就开创了这方面的先例。

是否消防员的电梯间是无烟的？

应当是，门在火灾期间是关闭的，电梯间则是密闭隔烟的。但也应当提供安全撤向楼梯的方法，以防止电梯关闭或者电源中断；或者只是简单地允许消防员谨慎的利用楼梯爬向其它各层楼梯，以到达实际着火层。

但是转动轴自身永远不会是密封的吧？

我们遵从合格设备层及消防安全工程师的智慧和要求，同时也与规则的权威性结合起来，并考虑到了烟囱效应和反烟囱效应的复杂性——这点在超高层建筑中正成为一个挑战，英国的规则可能会建议你这么做。我认为它们一开始是为伦敦的中低层建筑设定的，而当我们建设更高的高楼时，这一规则的实用性和有效性应当得到重新评估。例如，在美国的规则下，我认为如果你保护且密封了电梯间，那么真的就不需要再进一步了；也已经太迟了。封闭的电梯间乃是你防线上第一和最重要的东西。再说一次，我们把评述留给上面提到过的规范。

电梯系统是否是可持续的？

我认为在今天，由于升降机都是采用钢缆的，电梯应当尽可能有效地利用能量。由于最新可以利用的技术采用了永久磁铁，将它应用到电动机的转动元件中，可为电动机自身的零件增加3%-5%的效率，所以，电动机已经尽可能变得高效了。今天，完全再生式的电力驱动元件，有着接近于整个机械装置的功率因素，它是另外一个贡献者。有一个有趣的例子，在火灾期间，由于电梯运行于疏散模式之下，当一部满载的电梯向下运行时，轿厢要重于平衡力，当一部空电梯向上运行去承载其它人或货物时，平衡力要重于轿厢重量。因此，在此种重要的模式下，实际上有一个电力的净再生过程，此时，电梯的电力设备允许电力回到大楼的电网中，以供应其它的接电负载装置。在你最需要它的时候，电力实际上每次都再生了。对于高层建筑，我们也要求规划能够显示，电梯的传动系统可以在将来的某一天被拆除和替换。所以我认为就今天电梯所处的位置看，鉴于当前可以获得的电梯产品，电梯还是非常具有可持续性的。

世贸中心对于载客电梯有何影响？

高层建筑被不停地建设，甚至更多，所以其实没什么影响。我认为它主要是对消防规则发生了影响，旧有的规则已经过时了。那起事件发生之前，在我所参加的各类规则委员会中（针对紧急情况进行操控的美国机械工程师协会电梯规则委员会；各种旨在帮助纽约市消防局改进电梯的委员会），我有很长一段时间都在推动这种规则的改进。不幸的是，美国电梯行业中特殊的商业利益看起来让这些改进推迟了很多年，实际上，即使在保护电梯还不是他们职责的时候，同样的这些公司就已经在世界其他地方，在其它的规则要求下为消防员提供这类安全电梯了。但是，正如前面所提到的，美国的规则最终为消防员进行了改进，并且实际上已经跃升到了其它规则的前面，涵盖了人员疏散电梯，它本质上还是奠基在与英国消防队使用了数十年的电梯相同的设计之上。对于超高层建筑来说，这是重要的一步。当你需要疏散的时候，谁想要向下爬200层的楼梯？另外，就七星帆船酒店以及后来的纳赫勒港湾大楼（它们都是为迪拜规划的）而言，我们认为，将高层建筑与其附属大楼连接起来时，位于空中大堂的空中天桥，在整个的消防出口规划中将起到非常重要的作用。

the counterweight; when an empty car goes up to get another full load, the counterweight is heavier than the car. So during this important mode, there is actually a net regeneration of power, where the lift power electronics allow that power to go back to the building grid to help power other connected loads. Power is actually regenerated at a time when you may need it most. For tall buildings we also ask for plans to show that lift powertrains can be dismantled, and replaced, at a later date. So I think that for where the lifts are today, they are very sustainable for the current lift products available.

What effect did the World Trade Center have on elevatoring?

Well, tall buildings are certainly being built, even more of them, so there's been no effect on that. I think its main impact was on fire codes, which was way overdue. I had long been pushing for certain code improvements before that event on various code committees I had joined—the ASME elevator code committee for emergency operations and various committees to improve elevators for the FDNY [New York City Fire Department]. Unfortunately, certain commercial interests in the U.S. elevator industry seemed to delay such improvements for many years, even when the work to protect the elevator was not their work, and the same companies provided such protected elevators for firefighters elsewhere in the world under other codes. But, as mentioned earlier, U.S. codes have finally improved for firefighters, and have actually leaped ahead of other codes to cover occupant evacuation elevators, essentially based on the same designs used for decades for lifts for the British fire brigade. This is an important step for super-tall buildings. When you need to evacuate, who wants to take the stairs down 200 stories? By the way, for Al Burj and later for the Nakheel Harbour Tower, both planned for Dubai, we suggested that sky bridges at sky lobbies that connect to other sub-towers should be very useful in the entire fire egress plan.