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Green Vertical Transportation: More Than Just a Concept
绿色垂直交通：不仅仅是概念

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Robert Boog has been living in China for nearly a decade and involved in the elevator industry for over 15 years. Having studied Engineering at the University in Switzerland, his journey in China began in 2003 when he was appointed as the head of the Schindler Top Range Team in Southern China. In 2010, he was appointed Product Line Manager Asia Pacific for Schindler's Top Range Division and since 2013 has taken over the Product Line Director position globally. He currently resides in Shanghai where the global top range headquarters are located.

Robert Boog已经在中国生活了将近十年，从事电梯行业的时间超过15年。他在瑞士的大学所学专业为工程学，当2003年被任命为华南地区迅达高端团队的领导时，他开始了他的中国之行。2010年，他被任命为迅达高端部门的亚太地区产品线经理，自2013年起，他开始担任全球产品线总监。目前，他居住在迅达全球高端总部所在地上海。

Abstract

The environmental impact of high-rise buildings becomes a growing consideration as they multiply at an unprecedented scale to face the growing demands of global urbanization. The current pace set by urban developments, especially in emerging markets, has placed this as a priority and necessity for the generations of tomorrow.

Vertical transportation in this regard has generally been reduced to a contributor of more overarching elements of tall building certification. However, by creating a structured approach of short and long term measurements, encompassing all segments through pioneering systems and products, tall building managers can obtain clarity and a tangible input of vertical transportation equipment contributions to their landmark.

This paper seeks to outline the potential touch points of vertical transportation installations within high-rise structures, as well as outlining the long term benefits of maximizing the output current technology makes available within the market.

Keywords: Green, Vertical Transportation, Energy Recuperation, Destination Control, Traffic Simulation

摘要

面对全球城市化不断增长的需求，高层建筑正以史无前例的规模增加，高层建筑环境影响的问题也变得日益引人注目。由于目前的城市发展节奏极快，尤其在新兴市场中，因此这个问题是为了下一代所必须优先考虑的。

就这一点而言，垂直运输通常可以狭义地理解为高层建筑认证中的更加重要的元素的影响因素。但是，通过创建一种结构性的方法进行短期和长期度量，包含贯穿于前沿的系统和产品的所有环节，高层建筑管理人员可以清楚地了解垂直运输设备对于他们的地标性建筑的切实贡献。

本文致力于概括高层建筑中垂直运输装置的潜在作用，以及其先进技术最大程度地利用现有技术给高层建筑带来的远期利益。

关键词: 绿色、垂直运输、能量再生、目的地控制、交通模拟

With the population of the planet surpassing 7 billion people today and showing continuing signs of growth, the rapid development of urban centers and their effective management becomes of the utmost priority for the sustainable prolonging of human life on this planet. Today, rapidly developing countries like China have passed the urbanization rate of 50 Percent of their population . The gathering of individuals towards these concentrations of living space has required governments to start to think about cross effective solutions for the running of these communities. Further to this, as living standards rise globally, the expectation of the incumbent population evolves towards the provision of a safe, aesthetic, efficient, and sustainable living place. Although this has been a topic of discussion in the developed world for some time, the advent of new technologies and the urban and economic

随着目前 全球人口超过70亿并且呈现出不断增长的迹象，城市中心的快速发展及其有效管理成为最需优先考虑的事情，因为这这涉及到人类是否能在我们的星球上可持续地繁衍。当今，诸如中国等快速发展中的国家已经实现了人口 50%的城市化率。个人向这些生活空间集中点聚集，要求政府开始考虑有效的解决方案来运行这些社区。此外，随着全球生活标准提高，现代人口对生活质量的预期也朝着安全、美观、高效和可持续的生活场所而发展。虽然这是在发达国家中已经讨论了一段时间的话题，但是，新技术的出现以及城市和经济的推动 (如巴西、俄罗斯、印度和中国等国家也冲到了最前沿) 使得在过去十年间城市的可持续性达到了新的水平。有限的资源迫使我们对当前星球环境资源的发掘和使用承担更大的责任以及采取更加有效的使用方法，不管是通过经济管理，还是废物处理/可再生性等方法。毫无疑问，在这巨大的范畴内，正是这些城市

push, which has seen the countries such as the Brazil, Russia, India, and China come to the forefront, has brought urban sustainability to new levels in the last ten years. Finite resources have forced a greater liability of current excavation and use of the planets' environmental assets, as well as a more efficient methodology on usage, whether this is through means such as economic management or waste treatment/renewability. Within this huge scope, it is undoubtedly the developers of the urban skylines of tomorrow and their partners who play a decisive role in this course taken as demanded by market forces.

As the tall building market increases in competition as well as in total value, it is down to the suppliers to provide cutting edge technology and innovation to encourage their specific markets, as to allow a greater "marketability" of high-rise buildings for full tenant occupation. Specifically, for the vertical transportation segment, items of offering can be specified but not limited to, floor space increase, heightened security, energy savings, and efficient transportation. Furthermore, as technologies have evolved and will continue to do so in the near future, it is completely feasible that upcoming "game changing" technologies will play an essential part within possibilities, such as when destination control was established within this industry. All of these elements contribute towards the feasibility and sustainability of buildings, whilst at the same time, maximizing performance and the transit of people.

For the sake of this paper, the energy consumption and regeneration opportunities will be centered on three principal areas within a building, with which elevator power consumption can impact energy savings.

The Motor

Set at the top of the installation in the machine room (see Figure 1), the motor acts as the "muscle" of the elevator installation. With the development of Schindler's Green Motion Technology driven by highly efficient gearless motors and patented inverter system (Power Factor 1 technology), the system allows for the recuperation of surplus energy created during specific elevator load conditions. Depending on the load situation of the elevator system, mechanical energy returning from the elevator system can be returned to the power supply in the form of electrical energy. However, the misconception is that the energy retransmitted is of the uniform value, which is extremely relevant to the machines and its recuperation technology. Known as Total Harmonic Distortion (THD) that is the summation of all harmonic components of the voltage or current waveform compared against the fundamental ones; a common standard for elevator recuperation technology must fulfill THD lower than 5% to guarantee no interference to the building's power system.

The Car, the Hoistway and the Door

Energy efficient LED cab lights within an elevator car and their adjustment to movement detectors are one of the main contributors towards efficient power consumption in a building. Although taken as a single car unit, this consumption and effect to the overall grid is negligible. However, when this is multiplied by the number of installations in a high-rise, the impact is not to be overlooked. The latest technology and design of roller guide shoes has allowed for a smoother ride quality and improvement on reducing friction during elevator journeys, thereby reducing motor pull requirement. Reduced friction can also be applied to the door system mechanics, thereby increasing efficiency of door performance, specifically during closing and opening operation.

未来天际线的开发者们及其合作伙伴们，在此受市场力量制约的过程中扮演着决策者的角色。

随着高层建筑市场在总量上、竞争性上的增加，供应商应承担责任提供前沿技术和创新来激励其所在的市场，以帮助那些面对全租赁客户的高层建筑提高其销售能力。特别是对于垂直运输领域而言，提供的项目包括但不限于增加建筑面积、提高安全性、节能和高效运输。此外，随着技术不停歇的发展，在各种可能性中，很有可能那些即将来临的"改变游戏规则"的新技术将发挥至关重要的作用。例如此行业中的目的地控制技术。所有这些要素都有助于建筑的可行性和可持续性，同时也最大程度地优化了人员运输的性能。

以本论文的观点，能量的消耗和再生的机会乃集中在建筑物内的三个主要的领域，而电梯的能耗正是通过这些领域来影响其节能表现的。

曳引机

曳引机位于顶部机房中 (参见图1)，它就像电梯装置的"肌肉"。随着由高效无齿轮曳引机和专利的逆变器 (功率因数1技术) 为核心组成的迅达绿色动能技术的开发，系统允许对特定电梯负载条件下产生的能量进行回馈。根据电梯系统的负载情况，从电梯系统返回来的机械能以电能的形式返回电源电网。但是，有一种误解认为能量转换是一个相同的值，其实不然，该值与电机及其回馈技术息息相关。所谓的总谐波失真 (THD) 是与基础电压和电流波形相比之下电压或电流波形的所有谐波分量的总和; 电梯回馈技术的一个共同标准在于必须满足THD小于5%，以保证不干扰建筑的电力系统。

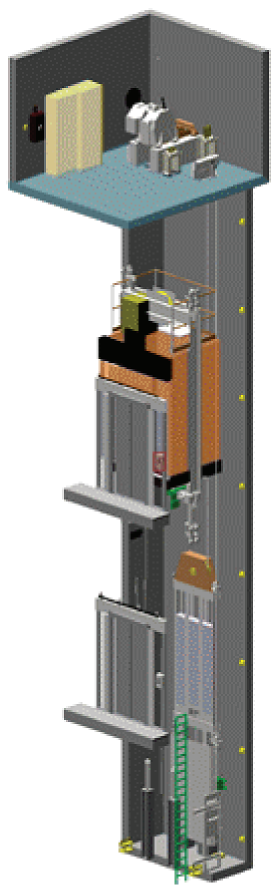

Figure 1. Typical elevator assembly (Schindler Internal)
图1. 典型电梯装配示意图 (迅达内部)

Elevator Control

The elevator control system savings can vary greatly from depending on which type of control system is used; conventional control systems, whereby the traditional stop by stop elevation is carried out for passengers and destination control technology, whereby each user is assigned an elevator upon entering a building. Depending on building requirements, the need for either system is varied. The higher efficiency of passenger transportation with destination control systems ultimately reduces the amount of elevators required in a building, thereby also, saving space and reducing the overall building carbon footprint. Other technology, such as attributes as ECO mode (discussed later in this paper), are also fundamental towards ensuring a smart function of a building and increased sustainability of projects.

Overlooking as the sector of Green elevation is quite large, it is imperative to break the topic down into three distinct pillars; Elevator Configuration, Elevator Usage, and Certification.

Elevator Configuration

During daily operation, these elevators travel in up- and down direction with different nominal loads. The counterweight balances the entire car weight, but only half of the car nominal load. Depending on travel direction and nominal load, the elevator drive operates either in a motoring mode or in a generating mode (Figure 2 to the right).

This physical circumstance finally feeds electrical energy back to the mains. The following (Table 1) indicates during which traffic modes the elevator drive works as a motor or as a generator. (Table 1)

The principle of using an electrical motor as a re-generator is known and has been applied for decades. However, recent developments in semi-conductor power technology has finally made it possible to apply this technology to elevator motors in such a way, that this motor can regenerate electrical energy most efficiently when driven as a generator (see Table 1).

The component which is able to provide power from the mains to the motor or returns power from the motor to the mains is known as the frequency converter. This converter is wired between the mains and the motor, as shown in the following Figure 3.

If the elevator motor works in the motoring mode, the incoming power is first rectified from alternating voltage (AC) with the line frequency into a direct current (DC). This DC is thereafter inverted back into an AC with a variable frequency and fed to the motor. The voltage and current level provide the power for the motor torque, whereas the variable frequency determines the rotating speed of the traction sheave and thus the speed of the elevator. When the elevator motor works as a generator, it feeds back the energy to the mains in the inverted way as before described. Thanks to the application of latest recuperation technology, the electrical power fed back to the mains is almost as clean as the incoming mains power.

"PF1" stands for "Power Factor One" technology and indicates that the electrical power switched in this component has no electrical losses in respect of the ideal sine-wave form and main frequency, thus can be regarded as "clean" power.

轿厢、井道和门

电梯轿厢内的节能LED灯及对运动探测器的调整是降低建筑能耗的主要贡献者之一。虽然对于一个单独的轿厢装置而言，该能耗和影响对于整个电网而言微不足道。但是，当把它乘以高层建筑中轿厢总量时，其影响就不可忽视了。滚轮导靴的最新技术和设计减少了电梯行程期间的摩擦力，实现了更加平稳的乘梯质量，因此，降低了电机牵引力。降低摩擦力也应用于门系统机构，因此，提高了门性能效率，尤其是在关门和开门操作期间。

电梯控制

根据采用的控制系统类型，电梯控制系统节能表现得非常不同;在常规控制系统中，为乘客采取提供常规的逐层停靠的操作;在目的地控制技术中，每个用户进入大堂穿过闸机就已经分配到一台电梯。根据建筑要求，对每个系统的需求也并不相同。使用目的地控制系统，乘客运输的效率提高，最终会优化建筑中要求的电梯数量。因此，也节约了空间并降低了建筑的总碳排放量。其它技术，例如: ECO模式的技术 (在本文的后文中进行讨论)，也以确保建筑的智能功能和提高项目的可持续性为根本。

整体看绿色提升部分的内容太大，因此，有必要把该主题划分为三个截然不同的小节;电梯配置、电梯使用和认证。

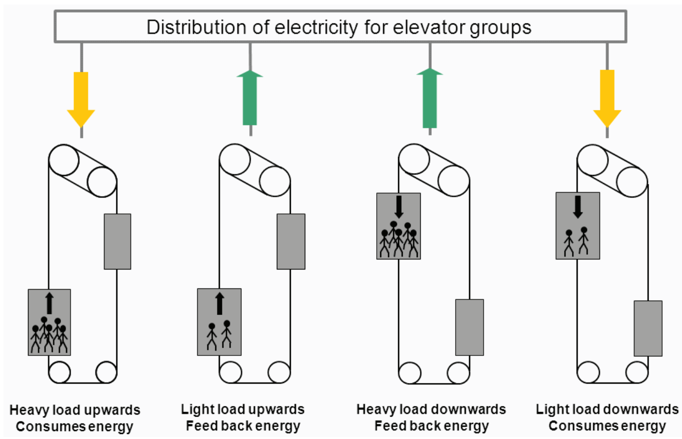

Figure 2. Distribution of electricity for elevator groups (Schindler Internal)
图2. 电梯组电源分配 (迅达内部)

		Payload	
		< 50 % of total load	> 50 % of total load
Car travel direction	Up	2) Generator	1) Motor
	Down	3) Motor	4) Generator

Typical traffic mode

1) & 3) Incoming traffic (morning)

2) & 4) Outgoing traffic (evening)

Table 1. Car regeneration per direction (Schindler Internal)
表1. 不同情况下轿厢能量提供 (迅达内部)

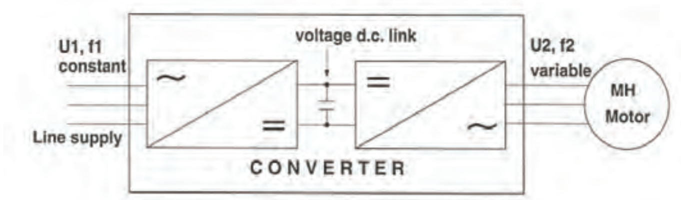

Figure 3. Frequency convertor that captures unused elevator energy(Schindler Internal)
图3. 频率转换器回收未使用电梯的能量 (迅达内部)

Elevator Usage

Elevator usage mechanisms are only part of the key towards making the most of a building's efficiency. A large part of the optimization of elevator components is done during the pre-tender of a building specification phase. For the sake of simplicity, this section will only focus on the most impactful of technologies during the elevator configuration phase, specifically Schindler PORT's ECO mode. Schindler's leading PORT Technology ensures highly optimized utilization of the elevator groups at all times of the day. The PORT system is an easily adaptable to low and high traffic situations which take place every day in the function of a building. The typical "peak" hours of a commercial building are situated in the morning rush (8:00am to 09:30am) and the lunch hour rush (11:30am to 13:00pm). The rest of the time the elevators are under less traffic intensity. However, under conventional control all elevators remain under full operation and hence full energy consumption. However, under, Schindler's PORT ECO mode the building's traffic situation is monitored under real time allowing the control system to adjust elevator waiting times in accordance to high "peak" or low traffic situations in accordance to meet the expected overall transportation performance. This in turn creates substantial saving of energy and consumption per elevator unit in a building system.

Although the entry of items such as destination control systems may cause an overlap as they interact in real time with elevator usage and traffic to re-adjust their own settings, by default setting them under the "Elevator Usage" and "Elevator Configuration". At the base the usage settings fall under the elevator configuration phase, as it is at this point that the decision to use items such as destination control or not are determined.

Certification

Unifying all energy measurements for customer review has been one of the biggest challenges, but also opportunities, with the recent increase in demand of sustainability within the high-rise market. Several independent bodies have been in measure to supply certification in accordance to international or local building requirements. Amongst them are several internationally recognized companies which are used to measure building energy efficiency under a global standard. The issue with a majority of these standardized test procedures is that they only reflect the partial truth about elevator energy consumption. The majority of these certification bodies revolve around generic formulas which account for the consumption of elevator energy as an individual unit. However, this does not consider elevator group consumption, but most importantly fails to account for building population, leaving then a gap open in terms of elevator usage measurements, especially in under elevated and over elevated buildings, which are a common occurrence within the high-rise market.

电梯配置

在日常操作期间，电梯在不同的额定负荷之下在上行方向和下行方向中行进。配重装置平衡整个轿厢重量，但仅为轿厢额定负荷的一半。根据行进方向和额定负荷，电梯驱动装置或在电机驱动模式中运行，或在发电模式中运行 (参见图2) 。

该具体情况最终会反馈电能到电网中。下面 (表1) 指出了电梯驱动装置在哪个交通模式中作为电机工作，在哪个交通模式中作为发电机工作。

使用电动机作为再生发电机的原理已经广为人知知并且已经应用了数十年。但是，半导体电力技术的最新发展才最终使得可以用这种方法把该技术应用到电梯电机上，当电机作为发电机时，可以非常高效地执行再生发电 (参见表1) 。

能够从电网提供电能给电机或者能够从电机把电能返回至电网的组件称作变频器。变频器连接在电源和电机之间，如下面图3所示。

如果电梯电机在电机驱动模式中工作，则来电首先从交流电 (AC) 整流为直流电 (DC) 。此后，该DC又转换回AC (变频) 并供应给电机。电压和电流水平决定了电机扭矩的大小，而可变的频率则决定了曳引轮的旋转速度并因此决定了电梯的速度。当电梯电机作为发电机工作时，它按照上述相反的方式把电能反馈至电网。由于最新反馈技术的应用，返回至电网的电能几乎像输入电网的电能一样洁净。

"PF1"代表"功率因数1"技术，指出了切换到该组件中的电能在理想的正弦波形和电源频率方面没有损失，因此可以视为"洁净"能源。

电梯使用

电梯的使用机制是获得最高建筑使用效率的唯一关键因素。大部分的电梯组件优化工作在制定建筑招标技术规范阶段完成。为了简单起见，本节仅着重介绍电梯配置阶段期间最具影响力的技术，特别是迅达PORT的ECO模式。迅达领先的PORT技术确保了电梯群在一天所有时段中的高度优化利用。PORT系统可以轻松地适应建筑功能中每天发生的低密度交通条件和高密度交通条件。商业大厦的典型"高峰"时间出现在早高峰时段 (上午8:00到09:30) 和午高峰时段 (上午11:30到下午13:00) 。其它时间里，电梯处于较小的交通强度下。但是，在常规控制下，所有电梯保持全开并因此为全能耗。但是，在迅达PORT ECO模式下，对建筑的交通情况进行实时监控，允许控制系统根据高"峰值"或低密度交通条件、根据预期的总体交通运营状态来调整电梯等待时间。结果这使得建筑系统中的每台电梯装置节约了大量能量和消耗。

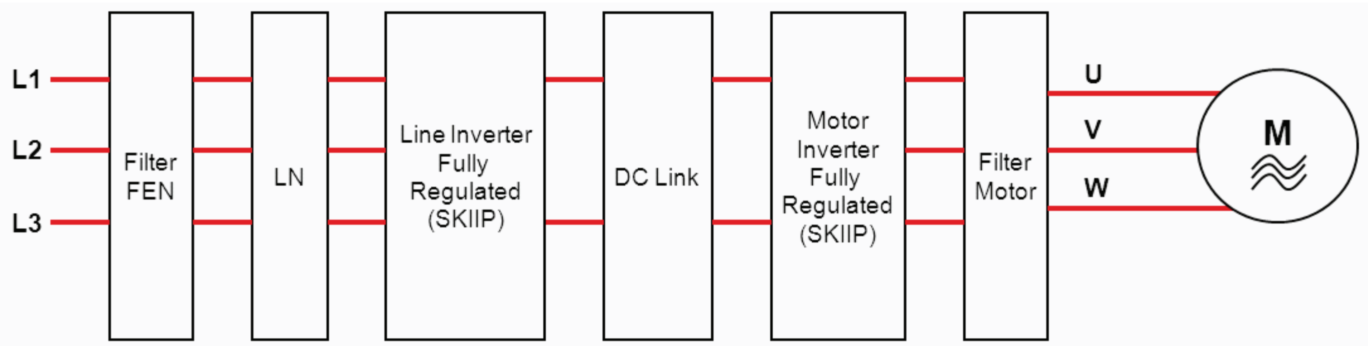

Figure 4. Electricity wiring diagram for typical lift construction (Schindler Internal)
图4. 典型电梯电路布线施工图 (迅达内部)

This lack of measurement has cause vertical transportation companies to extend their traffic measurement tools to address this issue and bring forward the energy consumption simulation and measurements to align with customer expectations. It also gives the full picture of energy consumption and regeneration simulation for each solution. For Schindler, this has been done through the company's very own traffic simulation software tool. By extending the company's patented algorithm technology, in alignment with the components sourced, and including them as an impact of a group wide elevator simulation, the sales engineers are able to extend the real time simulation of energy consumption according to usage and population flow to represent a reflection of true events permitting precise building planning.

Where Vertical Transportation Industry Can Support

Overall the vertical transportation industry can offer a variety of solutions to best the growing importance of the sustainability sector in the tall building arena. As this paper has demonstrated, the sector within the high-rise building industry known as "green" or "sustainable" is too a wide scope to be individually targeted through a single study. Furthermore, specifically towards the vertical transport industry, there is no uniform approach for measuring power regeneration from elevators, much less a clear division of which elevators impact where. This paper then promotes the clear segregation of three factors for the measurement of sustainability within the vertical transportation segment of high-rise buildings. Namely, Elevator Configuration, Elevator Usage, and 3rd party Elevator certification, as the three main pillars for future reference. It is essential that, not only is, elevator sustainability, promoted and held accountable within a uniform approach, which will, allow the further development of tall buildings globally on a par level. Each of these specific pillars represent a future platform to breakdown the essentials of elevator engineering simulations towards sustainable means. It also outlines an easy to follow segmentation of which measurements belong where, for non-technically driven members of the public.

By involving elevator suppliers in the earlier process of building design through traffic simulation and energy consumption simulations, allowing for effective and transparent measurements and data access to tall buildings control centers. As well as a fully aligned process and certification procedure agreed amongst all elevator companies, a full picture of building consumption, recuperation, and most importantly sustainability can be brought together.

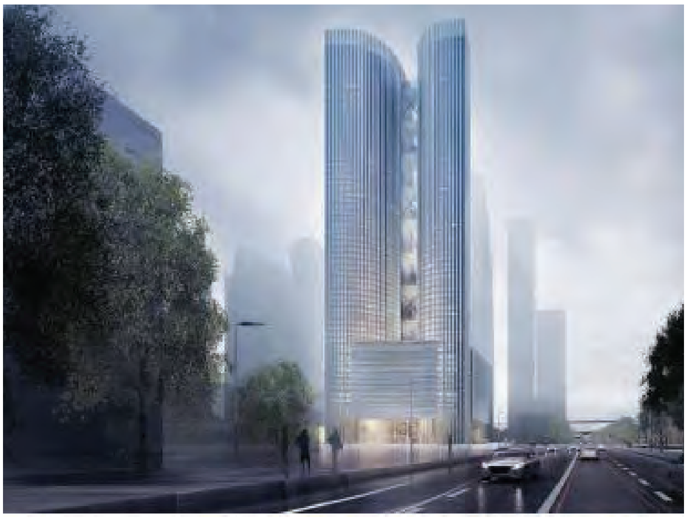

Figure 5. Plot 15 Moscow (Schindler Internal)
图5. 莫斯科15号地块（迅达内部）

虽然目的控制系统等项的输入可能造成重叠，因为它们实时与电梯使用和交通相互作用，以重新调整它们自己的设定值(在"电梯使用"和"电梯配置"下把它们设置为默认设定值)。但基本上，使用设定值被归入电梯配置阶段，因为正是在这个阶段决定是否使用目的地控制等功能项。

认证

随着最近高层市场中可持续性要求的提高，统一所有能量测量以供客户审核成为最大的挑战之一，但也成为一个机会。多个独立的机构已经在一定程度上根据国际或当地建筑要求提供了多种认证。这之中有几个国际公认的公司可以采用全球标准来测量建筑能效。大部分这些标准化测试程序都存在一个问题，就是它们仅仅反映了关于电梯能耗的一部分事实。大多数这些认证机构都围绕着一个通用的公式进行计算，该公式仅计算了电梯作为一个单独装置的能耗。但是，这并没有考虑电梯群的能耗，最重要的是没有计算建筑总人口，从而在电梯使用测量方面留下了一个缺口，特别是在大楼高配或低配电梯情况下，这在高层市场中也屡见不鲜。

这方面测量的缺失使得垂直运输公司把他们的交通测量工具扩展到能够处理该问题的程度并提出了能耗模拟以及测量方法，以达到与客户的预期一致。另外，它也展现了每个解决方案的能量损耗和再生模拟的完整画面。对于迅达而言，这通过公司自己的交通模拟软件工具来完成。通过扩展公司的专利算法技术，通过与外购组件相符，并通过把它们作为群范围电梯模拟的一个影响因素，销售工程师能够根据电梯使用和人口流动来扩展能量消耗的实时模拟，从而可以反映出真实事件的并允许对建筑进行精确的规划。

垂直运输行业的特殊贡献

整体垂直运输行业可以提供各种解决方案来最大程度地论证高层建筑领域中可持续性方面的越来越高的重要性。正如本文中所示，在高层建筑行业中所谓的"绿色"或"可持续性"部分是一个广阔的范畴，从而难以通过一个单独的研究来达成目标。另外，特别是对于垂直交通行业而言，没有一个统一的方法来测量电梯的再生能量，而对于哪个电梯影响了哪里则更没有一个清晰的划分。因此，本文提出了对三个因素的清晰划分，以测量高层建筑垂直运输领域中的可持续性。也就是说把电梯配置、电梯使用和第三方电梯认证作为三个主要支柱，以备将来参考。特别是(而不仅仅是)电梯可持续性，获得了促进并在统一的方法中保持其可信度，这将允许全球的高层建筑在相当的水平进一步发展。这些具体支柱的每一根都代表了一个未来平台，用于把电梯工程模拟的要素按照可持续的不同手段进行分解。对于公共的非技术性的公众成员而言，它也概括了一种容易遵守的、对哪种测量值属于哪里的划分。

通过交通模拟和能耗模拟，使电梯供应商参与到建筑早期设计过程中，允许高效和透明的测量方法并允许访问高层建筑控制中心的数据。除了所有电梯公司之间达成一致意见的过程和认证程序之外，还可以描绘出一幅建筑耗电、再生发电和最重要的可持续性的完整画面。