Title: **Advancements in Tall Building Vertical Transportation Design**

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Advancements in Tall Building Vertical Transportation Design
高层建筑垂直交通设计的进步

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Abstract

Advances in tall building vertical transportation systems are summarized for design professionals and developers in Asia. Elevator industry advances offer improvements in system performance, space efficiency, design flexibility, building operation, security, energy savings and life cycle costs. Specific topics include Destination Dispatch, access control integration, energy saving technologies, and reduced equipment space requirements. A summary of these elevator system design and technology opportunities is provided for multi-disciplinary consideration, as the effective adoption of these requires engagement with architect, engineer, developer and tenant stakeholders of the tall building design team.

Keywords: Elevator, Destination Dispatch, Access Control, Energy

摘要

本文总结了亚洲的设计专家和研发人员在高层建筑垂直运输系统上的设计改良。电梯行业的进步为行业内产品的系统性能、空间效率、设计灵活性、楼宇运行、安全性、能源节省和生命周期成本方面提供了显著改进。其中具体包括目的层调度、门禁控制集成、能源节省技术和减少设备空间的要求。这些电梯系统设计和技术机会的概述皆为多学科研究考虑而提供，因为有效采纳这些设计和技术需要高层建筑设计团队中的建筑师、工程师、研发人员和租客等众多利益相关者的共同参与。

关键词：电梯、目的层调度、门禁控制、能源

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Introduction

It is widely accepted that continued population growth will lead to increased urbanization. Elevators will continue to be a critical building system in this increasingly dense and vertical building environment. Fortunately, the global elevator industry is entering a fertile era, offering opportunities for more efficient elevator system design in many areas. These opportunities will help tall buildings be more commercially competitive, respond better to tenant needs, be more space efficient, more sustainable. This article is also premised on the notion that the implementation of many new elevator technologies requires multidisciplinary dialogue, and that these should be applied to not only landmark projects, but to the "volume" building market as well. The intended audience is architects, engineers, developers, owners and managers of tall buildings in Asia, who are interested in designing buildings with better elevator systems.

Destination Dispatch

Destination Dispatch is the most significant tall building elevator system development

引言

众所周知，人口的不断增长将导致城市化程度不断提高。在这个人口日益密集并充斥着垂直建筑的环境中，电梯在楼宇中仍将是一种重要的系统。幸运的是，全球电梯行业正进入一个全盛纪元，这为在许多领域设计出更高效的电梯系统提供了机会。这些机会将有助于确保高层建筑更具有商业竞争力、更好地应对租户需求、更高的空间效率并更具可持续性。另外，本文的前提概念是许多新型电梯技术的实施需要展开跨学科对话，并且这些技术应当不仅应用到地标性项目中，还应运用到"大规模"的建筑市场。本文的目标受众是对运用更完善的电梯系统设计楼宇感兴趣的亚洲高层建筑建筑师、开发商、业主和管理者。

目的层调度

自推出了自动电梯并取消了电梯服务员以来，目的层调度便成为了最具盛名的高层建筑电梯系统开发成果之一。迅达公司于1992年推出的Miconic10系统要求乘客在大堂而非在进入电梯轿厢之后输入他们的目的楼层。这种做法可充分利用"相同目的层"将同一批乘客分配至同一电梯，而不是随机分配。另外，这也令个别乘客的要求得到了识别。乘客目的层及任何个人

since the introduction of automatic elevators and the elimination of elevator attendants. Schindler's Miconic® 10 system, introduced in 1992, required passengers to enter their floor destinations in the elevator lobby, rather than after entering the elevator car. This allowed for passengers to be assigned to elevators taking advantage of "coincident destinations" with other passengers, instead of random assignment. It also allowed for recognition of individual passenger requirements. Passenger destinations and recognition of any individual requirements are communicated to the elevator system via hall keypad (see Figure 1).

Over the last ten years, all of the major elevator manufacturers have introduced Destination Dispatch systems. And yet while Destination Dispatch has become exponentially more popular since its original introduction, the share remains a small percentage of the total high rise elevator market, and is skewed towards high budget, prestige projects. To be clear, the advantages may be even more significant for the volume market of tall buildings, where cost and efficiency competition can be even more critical to competitive success. These advantages are summarized below.

Time to Destination

Destination Dispatch has introduced "Time to Destination" as a more comprehensive metric for evaluating elevator system performance. Time to Destination is the sum of both passenger waiting time and travel time. Traditional elevator traffic performance calculations allow for a "properly elevatored" building to satisfy interval and handling capacity criteria, and yet have unacceptably long travel times, particularly if a high number of floors are served by the elevator group. From the passenger's perspective, time is the most valuable resource consumed by the elevator system. Elevator manufacturers and consultants have tended to be conservative and understate the performance advantages of Destination Dispatch, perhaps due to fear of making unachievable claims or due to lack of an experience base and learning curve with properly implemented systems. It is also rarely discussed that Destination Dispatch travel times are most reduced for the highest floors served by the elevator group- a 50% reduction in travel time compared to conventional systems is not uncommon- which often have the highest paying and most demanding tenants.

Increased Handling Capacity

In a multi-group high rise building, Destination Dispatch may allow for the elimination of an elevator or even multiple elevators. Increased handling capacity can also accommodate increasing tenant densities over time, and the inevitable removal of elevators from service for maintenance, damage or malfunction.

Reduced Elevator Core Requirement

More efficient car loading allows for the use of smaller car sizes in many cases. Combined with a potential reduction in the number of elevators on large projects, total elevator core can be reduced. This may be the single largest opportunity proposed in this paper, as it positively impacts space and asset efficiency of both elevator and elevator related building systems, in terms of both initial and life cycle costs, and ultimately total carbon footprint.

Core Design Flexibility

Destination Dispatch systems do not require all elevators within a group to be identical in terms of floors served or other attributes such as car size, speed or even equipment type (see Figure 2). Due to the way finding advantages of Destination Dispatch elevators, there is also greater potential flexibility in elevator core arrangement. The increased flexibility allowed for building and elevator core design is still being

要求的识别都可通过大堂内的键区传递给电梯系统（见图1）。

在过去的十多年中，所有主要电梯制造商纷纷都推出了目的层调度系统。然而，当目的层调度自其最初推出以来变得越来越受欢迎时，其市场份额仍仅占高层建筑电梯市场的一小部分，并且向高预算、有影响力的大型项目靠拢。更明确地说，其优点对于高层建筑的大规模市场可能更为显著，因为在该市场中成本和效率竞争力对取得成功更为关键。这些优点将在下文中逐一论述。

抵达目的层时间

目的层调度系统现已推出了“抵达目的层时间”并将其作为评估电梯性能的一个更全面的度量标准。抵达目的层时间指乘客等待电梯的时间与乘坐电梯的时间之和。传统电梯运输性能的计算法则使拥有“标准配置电梯”的建筑物能够满足间隔停顿时间和输送能力标准，然而超长的行程时间仍令人难以接受，尤其是在通过电梯群有许多楼层都被选择的情况下。从乘客的角度来看，时间是电梯系统消耗的最宝贵资源。电梯制造商和顾问现已趋向于持保守态度，他们低估了“目的层调度”的性能优势，这可能是因为害怕作出无法实现的承诺，或是由于缺乏经验基础以及对正确操作系统的认知概念。另外，也很少有人提到目的层调度可最大限度地减少由电梯群控制的最高楼层的行程时间—相比传统系统，行程时间减少50%并不罕见—只是往往需要支付最高额的租金，以及有要求最苛刻的租户。

提升输送能力

在多组高层建筑中，目的层调度使得去减少一部甚至多部电梯变成可能。随着时间的推移，经提升的输送能力还可承载越来越多的租户人数，这也省去了由于减去电梯因维修、损坏或故障停止服务而引起的麻烦。

降低电梯核心要求

在许多情况下，更高效的轿厢乘载增加了小尺寸轿厢的使用率。考虑到大型项目中电梯的数量可能发生减少，电梯的总核心要求也得到了可降低的可能。这也许是本论文中提出的唯一一个最大的机遇，因为就初始成本和生命周期成本以及最终的总碳排放量而言，这将对电梯及与建筑系统相关电梯的空间和资产效率产生积极影响。

灵活设计核心

目的层调度系统并不要求一个电梯群内的所有电梯在服务楼层或其它属性方面保持一致，如轿厢大小、速度或者甚至设备类型（

Figure 1. Schindler PORT keypad. (Source: Schindler Elevator Corporation)
图1. 迅达终端调度键盘（来源：迅达电梯公司）

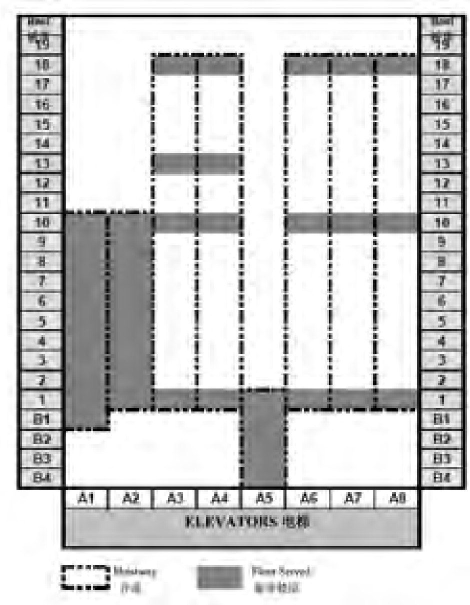


Figure 2. "Asymetrical" elevator group. (Source: GVK-ECS, Inc.)
图2. "非对称"电梯组（来源：GVK电梯咨询服务公司）

explored incrementally, but the long term design impact can be revolutionary.

Individualization

Destination Dispatch elevators interface allow for a customized response and special features to address unique passenger needs, whether they be tenants, visitors, passengers with disabilities, VIP's, building engineers, or brokers and potential tenants. When integrated with access control, this also allows for much more sophisticated management of traffic (discussed in more detail in the next section). Schindler has pioneered this approach with their ID and PORT systems.

Accessibility

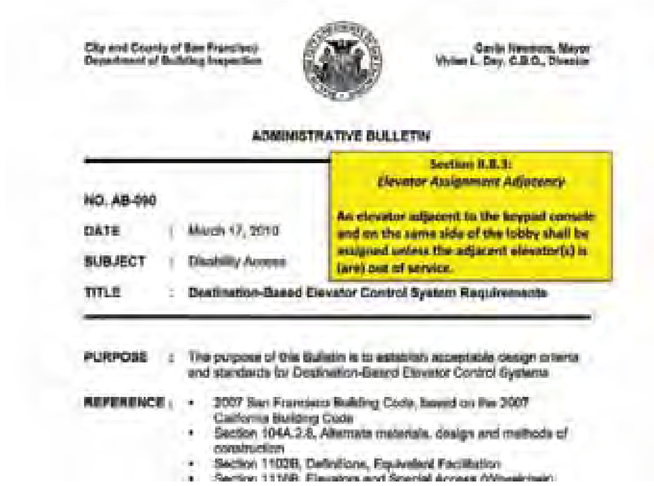
The experience of the last 15 years has shown that Destination Dispatch systems are overall superior for persons with physical disabilities, due to the improved way finding, and the ability to recognize individual requirements for audible or visual signals, and for increased boarding time and car space. There is a clear need for the development of improved and international standards in this area, with input from the disabled community. The City of San Francisco has adopted its own accessibility standard for Destination Dispatch elevators, which includes the innovative requirement that disabled passengers be assigned an elevator adjacent to their location in the elevator lobby (see Figure 3). The elevator industry has recently introduced touch screens in place of mechanical buttons and keypads. Guidelines will need to be developed to make these properly accessible, and for their eventual incorporation into international building codes.

Ease of Use

New users typically require one trip to learn how to use the system. Concerns over usage difficulties have not been borne out by experience. It is not unlike using a digital touch pad phone for the first time.

Modernization

In the US, Destination Dispatch has been widely adopted for the modernization of elevators in existing buildings. The primary reason appears to be that in existing buildings, the owner and manager are more directly involved in satisfying tenant elevator requirements, due to tenant retention concerns or the need to attract new tenants. For


City and County of San Francisco
Department of Building Inspection

ADMINISTRATIVE BULLETIN

Section 8.8.3:
Elevator Assignment Adjacency

An elevator adjacent to the keypad console and on the same side of the lobby shall be assigned unless the adjacent elevator(s) is (are) out of service.

NO. AB-090
DATE : March 17, 2010
SUBJECT : Disability Access
TITLE : Destination-Based Elevator Control System Requirements

PURPOSE : The purpose of this Bulletin is to establish acceptable design criteria and standards for Destination-Based Elevator Control Systems

REFERENCE :
- 2007 San Francisco Building Code, based on the 2007 California Building Code
- Section 104A.2.8, Alternate materials, design and methods of construction
- Section 1102B, Definitions, Equivalent Facilitation

Figure 3. San Francisco adjacency requirement. (Source: City and County of San Francisco, Department of Building Inspection)
图3. 旧金山相邻要求（来源：旧金山县市建筑检验部）

见图2）。由于目的层调度电梯具有寻路优点，因而其在电梯核心配置方面也具有更大的潜在灵活性。提升建筑物和电梯核心设计的灵活度目前仍处于增量式探索阶段，不过一旦成功对设计的长期影响将是革命性的。

个性化

目的层调度电梯界面为特殊乘客的需求提供了定制化的回应和特殊的功能，无论他们是租户、访客、残疾人乘客、贵宾、建筑工程师还是中介或潜在租户。结合门禁控制集成，目的层调度电梯在运输管理上将变得更为成熟（在下一节中将更详细地论述）。迅达公司通过他们的ID和PORT终端系统开创了这种方法。

无障碍性

过去15年的经验表明，目的层调度系统对于身体有残疾的乘客来说是整体上最卓越的电梯系统，这是由于经过改进寻路方式、通过声音或视觉信号识别个体要求的能力以及增加的上梯时间和轿厢空间。随着残疾人社区的投入，国际上对发展和改善这一领域具有明确的需求。旧金山市现已正式通过了符合自己的目的层调度电梯的无障碍标准，其中包含了在大厅处就将残疾人乘客分配至最毗邻他们住所电梯的创新要求（见图3）。电梯行业最近也推出了取代机械按钮和键区的触屏。如今需要做的是普及指导方案，以使得这些标准获得适当的实施，并能够将其最终纳入国际建筑准则。

易于使用

新用户通常需要乘坐一次电梯来了解如何使用该系统。经过试验目前并不存在使用难度。这就和首次使用Itouch、Ipad和Iphone没什么不同。

更新改造

在美国，目的层调度已在现有电梯的更新改造项目中广泛使用。主要原因在于，在现有的建筑中，由于希望留住租户的关注或吸引新租户，业主和管理方更直接地参与到了满足租户对电梯的需求中来。对典型的新建设项目而言，总承包商和建筑师通常对电梯系统的设计和选择最具影响力。除非业主或开发商在设计初期就很专注电梯系统，否则电梯的机遇并非是在任何一个细节上对其进行评估。这主要是因为，除去一些对项目预算和进度具有直接影响的决策外，大部分设计已基本上根据传统的假设完成了设定。

电梯集成门禁控制系统

当适当连接和配置门禁控制系统后，目的层调度系统可在一天内或定时自动管理建筑内任何楼层之间的垂直运输，甚至能够精确

typical new construction projects, the general contractor and architect are often the team members with the greatest influence on elevator system design and selection. Unless the owner or developer decides to focus on elevator systems early in design, elevator opportunities are often not evaluated in any detail, except for decisions that have immediate impact on project budget and schedule, based on a design that is already largely fixed based on traditional assumptions.

Integration of Elevators and Access Control

When properly interfaced and configured with an access control system, Destination Dispatch provides the capability to automatically manage vertical traffic in the building, from any floor, to any floor, based on day or time clock, for each passenger on an individual basis (!). Tenant, visitor and building workers are granted access rights to floors by the access control system, and so the elevator dispatching needs to interface with the access control system. In the past the interface between elevators and access control was treated as a minor construction coordination item, requiring little design attention. That is no longer the case. The proper integration of these is now critical to the operation of a properly designed tall building, and not surprisingly, there has been significant investment and innovation in this area by both the elevator and access control industries.

System Interface

There are two basic approaches for the software interface between the elevator dispatching system and the building access control system. The first approach requires a custom serial interface, whereby floor access is granted by the access control system to the elevator control system. This is the approach taken by Kone, Mitsubishi, Otis and ThyssenKrupp. Given the numerous elevator and access control system manufacturer combinations, there is a need for numerous unique interfaces.

The second approach incorporates the access control features within the elevator system itself. This is the approach taken by Schindler with the Schindler ID and PORT systems. This approach has functionality and simplicity benefits. However, it still requires a manual or automatic synchronization method of the elevator system user database with access control system user database.

Inter-Floor Traffic Control

A properly configured elevator and access control system allows the building manager to manage their "building transportation system" to serve the specific needs of the tenants. In most cases, tenants wish to travel freely between their floors, but want to restrict travel by others to their floors (see Figure 4). The obvious benefit of doing this is improved building security. But perhaps even more important, effective interfloor traffic control can reduce the overall traffic demand and increases the surplus capacity of the elevator system. Stated differently, a building without such a system, all other factors being equal, will often require additional elevator system capacity, and so carries inefficiency burdens on core space, elevator and building costs, energy use, and ultimately, asset return.

Passenger Separation

Individual recognition of passengers allows for different passenger groups to be separated by the assignment to different elevators (see Figure 5). While this may degrade overall system performance within an elevator group, it can also allow for otherwise separate elevator groups to be combined, allowing for sharing unused capacity between what would otherwise be separate elevator groups in a traditional system.

在每位乘客（！）。该门禁控制系统允许租户、访客和建筑工人的出入，因此电梯调度系统需要与门禁控制系统连接。在过去，电梯与门禁控制系统之间的连接被视为一个并不重要的建筑协调项目，只得到很少的设计关注。如今情况却已不再如此。两者的适当集成是完美设计的高层建筑运行的关键，因此，电梯和门禁控制行业一直在这一领域投入大量投资和创新也并不奇怪。

系统界面

电梯调度系统与楼宇的门禁控制系统之间有两种基本的软件接入方法。第一种方法需要一个自定义的串行接口，门禁控制系统通过该接口向电梯控制系统授予楼层出入权。通力、三菱、奥的斯和蒂森克虏伯等公司均采用这种方法。鉴于众多不同的电梯和门禁控制系统制造商相互，因此需要提供众多特定的接入端口。

第二种方法是将门禁控制功能直接融入到电梯系统的本身。迅达公司及其推出的ID和接入口终端控制系统均采用这种方法。这种方法具有功能性和简洁性等优点。然而，这种方法依然需要使电梯系统用户数据库与门禁控制系统用户数据库手动或自动同步

层间交通控制系统

适当配置的电梯和门禁控制系统让大厦经理们能够良好地管理他们的“建筑运行系统”，以满足租户的特定需求。在大多数情况下，租户都希望能够自由的往返于他们所在的楼层之间，同时希望限制他人前文他们的楼层（见图4）。这样做的好处是提高了楼宇的安全性。但也许更重要的是，有效的层间交通控制系统可以减少整体的交通需求，并增加电梯系统的运输量。换句话说，所有其它配置相同，但未配置这种系统的楼宇往往需要额外的电梯系统载重量，因而需要承受主体空间使用效率低、电梯和建筑物成本高、能源利用率低以及最终得到的资产回报率低等额外支出。

乘客分流

乘客个体识别允许将不同乘客组分配至不同的电梯进行分流（见图5）。虽然这可能降低一个电梯组内的整体系统性能，但其还允许以其它方式将乘客组划分在一起的电梯群，从而允许共享在传统系统中以其它的方式在电梯组之间区分的未使用的载重量。

访客管理

最先进的门禁控制系统应包含访客管理系统，租户可直接通过门禁控制系统管理和授予他们的访客出入权。除了提供更全面的责任之外，访客处理效率也得到了提高，并且安保人员的成本支出也可以降低。鉴于电梯集成门禁控制系统的重要性，在设计时应

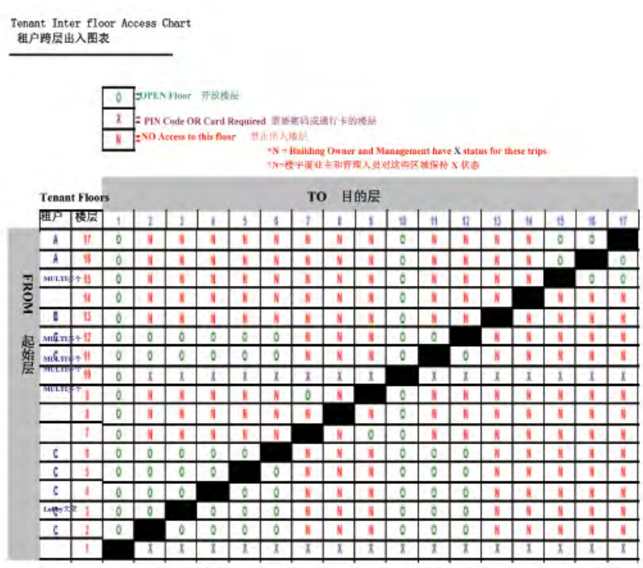


Figure 4. Control of inter-floor traffic. (Source: Schindler Elevator Corporation and GVK-ECS, Inc.)
图4. 层间交通控制（来源：迅达电梯公司和GVK电梯咨询服务公司）

Visitor Management

A state of the art access control system should includes a visitor management system whereby tenants manage and take responsibility for granting their visitor's access directly through the access control system. Aside from providing improved accountability, visitor processing efficiency is improved and security staffing costs can be reduced. Given the importance of elevator integration with access control, visitor processing, access and elevator assignments should be considered in design. Self-service visitor access control, such as via touch screens, interfaced to the elevator system, will be more widely adopted as the benefits of this approach become more widely known (see Figure 6).

Reducing Energy Consumption

The total carbon foot print of an elevator system over its life cycle is the combination of elevator equipment manufacturing and installation (the equipment itself) , elevator related building construction (such as hoistways and equipment spaces), elevator system life cycle usage (such as electrical consumption), and elevator related building system consumption (such as machine and controller space cooling). There remains considerable opportunity to better define and calculate these costs, particularly given the long life cycle of tall building elevator systems, and the impact of elevators on building costs for construction and operation. A very small minority of tall building projects attempt to empirically evaluate elevator energy consumption (and carbon footprint) with any sophistication. The reality is that most projects pay little attention to these. Opportunities for elevator energy consumption reduction are summarized below.

Number of Starts & Consumption Per Start

These key metrics and the related calculations of elevator system energy consumption receive little or no attention on the majority of elevator projects (see Table 1). The superior traffic handling of systems such as Destination Dispatch can lower energy consumption simply by reducing the number of elevator starts for certain traffic scenarios. Other methods are available to reduce consumption per start are summarized below.

Regenerative Drives

The power consumed per elevator start can be reduced by using an efficient drive system, such as a near unity power factor regenerative drive. A regenerative drive returns power back to the building when full or heavily loaded elevators travel down and empty or lightly loaded elevators travel up, effectively making the electrical meter for the elevator spin backwards. High quality regenerative drives also output less machine room heat, have cleaner electrical harmonics and automatically shut down during idle periods. Regenerative drive features are now also offered for down escalators as well.

Counterweight Balancing

The counterweight of a typical high rise elevator weighs more than the car by approximately 40% of the car capacity. To the extent that the car and counterweight are more equally balanced, the energy required to run the elevator is reduced. Elevator manufacturers are beginning to develop energy saving dispatching modes to take advantage of this.

Elevator Energy Monitoring

It is difficult to improve something that is not measured. There is not yet an elevator or building industry standard protocol for elevator system power consumption monitoring and integration into Building Management Systems. Few (if any) buildings are being designed with the capability for accurate, real time measurement of elevator system

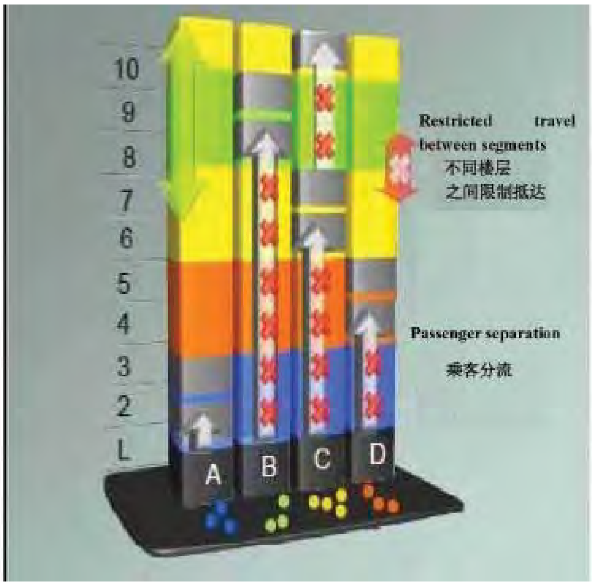


Figure 5. Passenger Separation. (Source: Otis Elevator Company)
图5. 乘客分流（来源：奥的斯电梯公司）

考虑访客处理、门禁和电梯分配等功能。将更广泛地采用访客自助出入控制，如通过触摸屏以及连接到电梯系统等，这种方法的好处将为越来越多人们所熟知（见图6）。

降低能源消耗

电梯系统在其生命周期内的总体碳排放为电梯设备的制造和安装（设备本身）、电梯相关建筑物的施工（如井道和设备空间）、电梯系统生命周期内的使用（如耗电量）和电梯相关建筑系统的能源消耗（如机房和控制器的空间冷却）。目前仍有相当大的机会可以更好地定义和计算这些成本，特别是鉴于所有的建筑电梯系统超长的生命周期和电梯对建筑施工和运行成本的影响。极少数高层建筑项目曾尝试以实际为基础评估具有复杂度的电梯能源消耗（及碳排放）。现实情况却是，大部分的项目很少注意这些问题。降低电梯能源消耗的方法将在后文中具体描述。

启动次数&单次启动的能耗量

电梯系统能耗量的这些关键指标及相关计算在大多数电梯的项目中很少或根本没有引起注意（见表1）。一些系统（如目的选层调用系统）的卓越运行处理能力只需通过减少在某些运行情况下的电梯启动次数即可降低能源消耗。一些可降低每次启动能耗量的其它方法将在后面的文章中总结。

再生驱动系统

可以通过采用高效驱动系统来降低电梯每次启动所消耗的功率，比如整功率因素再生驱动系统。当完全或较重加载的电梯往下和空载或者较轻加载的电梯往上运行时，再生驱动系统可将功率返回到建筑物，从而使电梯电表有效地向后旋转。高质量的再生驱动系统还会输出更少的机房热量、具有更清洁的电力谐波，并且在可闲置期间自动关闭。下行的自动扶梯同样可以提供再生驱动系统功能。

对重平衡

典型高层建筑的电梯对重比轿厢载重大约要重40%。在轿厢和电梯对重相对平衡的情况下，电梯运行所需的能源可以降低。电梯制造厂商已经开始研发节能调度模式，以充分利用这一节能的机会。

电梯能源监控

要改进某些无法用数据测量的性能通常很困难。目前尚无关于电梯系统功耗监测和集成至建筑管理系统的电梯或建筑行业的标准协议。很少有（如果有的话）建筑在设计时会考虑到准确、实时

Figure 6. Visitor self-check in. (Source: G4S)
图6. 访客自行登记系统（来源：G4S保安公司）

	Speed 速度 Capacity 额定载重量 Runs/Day 运行次数/日	1200 (6.0) FPM (m/s) 2300 (1.0) lbs (kg) 1200	
Drive / Motor Type 驱动系统类型	kWh/ day (Estimate) 千瓦时/日 （估计值）	Relative kWh Consumption Savings 相对千瓦时消耗量节省	
		Value 数值	%
m-g DC (Regen)m-g 直流（再生）	103	1.000	0%
SCR-DC (Regen)SCR 直流 （再生）	94	0.912	8.8%
Quattro PWM-DC (Regen) 全时四驱PWM直流（再生）	56	0.539	46.1%
Inductive AC non-Regen 感应交流（非再生）	103	1.003	-0.3%
Inductive AC w/ Regen 感应交流/再生	102	0.994	0.6%
PM AC non-Regen 永磁交流（非再生）	70	0.676	32.4%
PM AC w/ Regen 永磁交流/再生	49	0.477	52.3%

Table 1. Gearless Comparison
表1. 无齿轮驱动比较

power consumption, separate from other building systems. This is not a difficult development task, and this capability could be readily available should an owner or developer ask for it. As with other opportunities, it requires coordination between the elevator manufacturer and other members of the design team.

Energy Rebates

While not yet common, some utilities in the U.S. have begun to offer rebates for the use of elevator energy savings technologies, such as near unity power factor regenerative drives.

Reducing Equipment Spaces

For nearly a century, the standard elevator system design located an electric hoist machine (usually with a controller and drive system) in oversized, overhead elevator machine room. While the basic overhead equipment arrangement for tall buildings will remain for the foreseeable future (along with continued creative architectural approaches to hide it), the elevator industry has become more creative in recent years regarding the reduction of the space requirements for elevator equipment. Elevator system arrangement and layout constraints previously defined and accepted as immutable have been challenged and offer creative opportunities for building designers.

"Machine Room Less"

The Kone MonoSpace™ "machine room less elevator" (MRL) was introduced in 1996. The key design element of the MonoSpace™ was a slim axial linear AC gearless hoist motor, located in the top of the hoistway above the counterweight, allowing for the elimination of the overhead machine room. The MonoSpace™ also allowed for the elimination or reduction of the controller space as well. The space savings, and elevator and building cost savings, of MRL's are now well known. In a few short years, MRL's became the dominant elevator product type for low and mid rise buildings (up to approximately 20 floors), and for low and mid rise applications in tall buildings as well.

Controller and Machine Room Space

For higher rise, speed and capacity applications where MRL elevators are not feasible, there still are opportunities to decrease the size of the machine room. The Kone MiniSpace™ is basically a larger MonoSpace™, but with a machine room no larger in plan than the elevator hoistway (see Figure 7). This more efficient use of machine and controller space in tall buildings will likely be benchmarked by other manufacturers.

Door Space

The space required by the elevator car and hoistway door system offers

测量电梯系统独立于其它建筑系统的功耗的能力。这并非一项困难的研发任务，并且如果业主或开发商要求的话，现在就可以提供这种能力。与其它节能的做法一样，这也需要电梯制造商和设计团队其他成员之间的良好协调。

能源补贴

虽然尚未普及，但美国一些公共事业单位已开始就电梯节能技术的使用提供补贴，比如类似整功率因素的再生驱动系统。

减少设备空间

近一个世纪以来，标准电梯系统的设计都是将电动曳引机（通常带有一个控制器和驱动系统）安置在超大的顶部电梯机房内。虽然高层建筑顶部基本设备的安设在未来的一段时间内仍将被保留（同时继续开发创造性的结构方法将其隐藏），但在减少电梯设备空间要求方面，电梯行业近年来已变得更具创造性 。曾经被定义并视为无法改变的电梯系统排列和布局限制如今已经受到了挑战，为建筑设计师提供了创新的机会。

“无机房电梯”

通力公司于1996年推出了MonoSpace无机房电梯（MRL）。MonoSpace设计的关键元素为超薄的轴向线性交流无齿轮曳引驱动系统，安置于配重上方的井道顶部，从而减少了机房的需要。MonoSpace还去除或者减少控制器空间。无机房电梯所实现的空间节省及电梯和建筑成本的节省在行业内已是众所周知。在短短的几年时间里，无机房电梯已成为中低层建筑（最高约20层）和高层建筑内的中低层应用中占主导地位的电梯产品。

控制器和机房空间

对于更高层的建筑来说，无机房电梯在速度和载重量方面的应用并非实际可行，但仍存在减少机房空间的机会。通力公司推出的MiniSpace小机房电梯实质上是一款大型的MonoSpace无机房电梯，但按照设计，机房空间并非大于电梯井道（见图7）。机房和控制器的空间在高层建筑内的这种更高效的利用，将成为其他制造厂商的生产基准。

轿门空间

电梯轿厢和井道门系统所需的空间在空间减少方面提供了类似的机会。虽然井道门空间只减少了几厘米，节省的空间可能非常有限，但当加上经过所有楼层时的轿门关合，节省的空间会显著增加，尤其是当所节省的空间具有可用性和可以租用时。

Figure 7. Kone MiniSpace™. (Source: KONE Corporation)
图7. 通力MiniSpace小机房电梯（来源：通力集团）

a similar opportunity for space reduction. While a reduction of a few centimeters of door space savings may appear small, it can represent a significant gain when multiplied across all elevator door openings, on all floors- particularly when the space saved is usable and rentable.

Counterweight Space

There remain opportunities for hoistway space savings through the use of more space efficient counterweight designs. As with doors, the space savings becomes significant when multiplied across the elevator hoistways, the full height of the building. An extreme example of counterweight space savings is the Kone MaxiSpace™, an electric elevator with an innovative 6:1 roping arrangement that eliminates the counterweight altogether. The MaxiSpace™ was proposed initially as a retrofit product for existing, older low rise buildings in Europe, and is limited to low speeds and small capacities. However, it does indicate the significant potential for innovation in this area.

Double Deck

For shuttle elevator applications, such as to very tall building observation decks, double deck elevators offer acknowledged traffic handling benefits. However, for local service, Double Deck elevators have traditionally been limited by the difficulties of efficiently loading and unloading two decks simultaneously. Destination Dispatch has been combined with double deck local elevators on a number of recent projects and may offer improvements to both dispatching and quality of passenger service.

Two Cars in Single Hoistway

A radical expansion of the Double Deck concept occurred in 2003 when ThyssenKrupp introduced TWIN (see Figure 8). While two cars in a single hoistway had been pondered before, it had never been a feasible design proposition. TWIN is in fact a Double Deck system in which the two decks travel independent of each other, and so are not constrained to only serve contiguous floors. TWIN can allow for the elimination of entire hoistways, saving both space and building construction cost. However, the elevator system and space planning process for TWIN is complex. A TWIN car can not serve both top and bottom floors, and so not all elevators in a group can be TWIN units. Given the resulting floor service asymmetries, Destination Dispatch is a required feature of TWIN.

配重空间

目前仍有通过采用空间效率更高的配重设计来进一步节省井道空间。与轿门一样，当增加电梯井道所通过的建筑高度时，空间效率的节省将变得更显著。配重空间节省的一个最显著例子是通力公司推出的MaxiSpace电梯，其创新性的6:1挂绳配置严格控制了配重的需要。MaxiSpace最初作为欧洲低层旧梯的更新改造产品推出，仅应用于低速梯和小载重量电梯。然而，它的推出，证实了在这一领域进行创新的巨大潜力。

双层轿厢

对于上下运行的电梯应用而言，例如非常高的建筑物观景台，双层轿厢电梯可提供公认的运行处理优势。然而就各地的运行而言，双层轿厢电梯始终受到无法同时高效加载和卸载双层轿厢的限制。目的选层调用系统在近期完成的多个项目中已和当地双层轿厢电梯组合使用，在调用和乘客服务质量方面做出了很大的改进。

两个轿厢在同一井道中独立运行

当蒂森克虏伯公司推出TWIN双子电梯系统时（见图8），双层轿厢的理念在2003年发生了根本性的拓展。虽然业界曾经也考虑过两个轿厢在同一井道中独立运行，但从来没有提出过可行的设计主张。TWIN双子电梯系统事实上就是一种双层轿厢系统，两个轿厢彼此独立运行，并不局限于服务相连的楼层。TWIN双子电梯系统满足整个井道的需求，并且既节省了空间又节省了建筑和施工成本。然而，TWIN的电梯系统和空间规划过程十分复杂。一部TWIN双子电梯的轿厢不能同时在顶部楼层和底部楼层运行，因此，并非一个电梯组内的所有电梯都可以做成TWIN双子电梯。鉴于因此而造成的楼层服务不对称，目的选层调用是TWIN双子电梯所必须的功能。

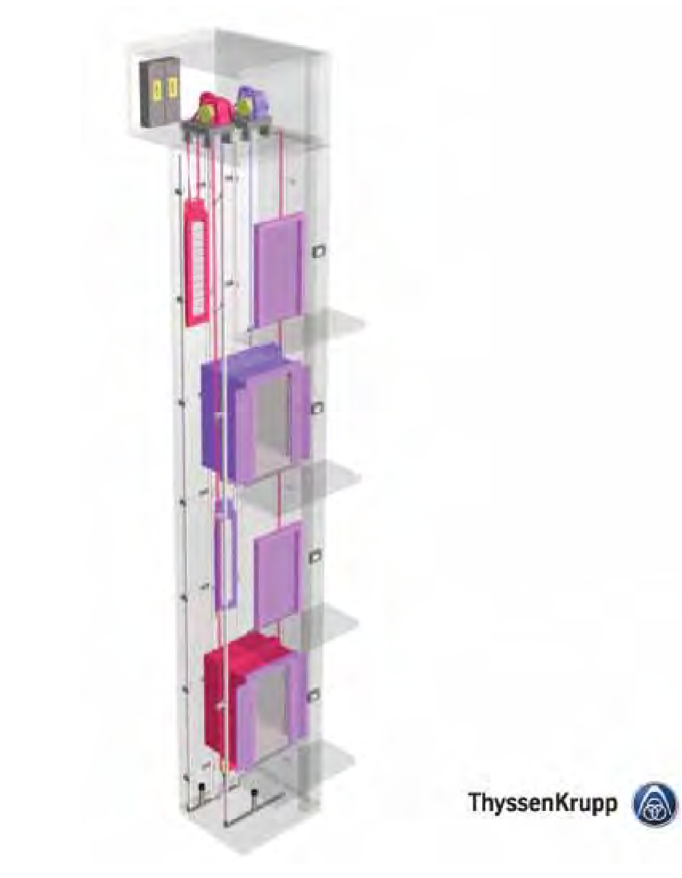


Figure 8. ThyssenKrupp TWIN. (Source: ThyssenKrupp Elevator)
图8. 蒂森克虏伯TWIN双子电梯系统（来源：蒂森克虏伯电梯公司）