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Elevator Use During Construction Time of Tall Buildings
高层建筑施工期间使用电梯的好处


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Abstract

The efficiency of construction work is affected by the time required to transport workers between ground level and their worksites. Usually, exterior construction hoists are installed outside the building for the transportation of construction workers. However, the permanent hoistways of the building can already be used to transport workers even during the construction time. These elevators have a temporary machine-room that is moved floor-by-floor in jumps upwards as the building gets taller and taller. Compared to the exterior construction hoists, jump elevators can have higher lifting speeds, which results in higher handling capacity and shorter waiting times. Thus, less time is lost in waiting for transportation. This paper introduces a method to calculate the time lost in vertical transportation in a construction site. Using the method, it is shown how working shift and location arrangements affect the vertical transportation.

Keywords: Jump Elevator, Construction Time Use, Traffic Analysis

摘要

在地面与高层施工现场之间来回运输工人所需的时间会影响建筑施工效率。通常情况下，承建商会在建筑外墙上安装外部施工升降机，用于运输建筑工人。然而，建筑的永久井道在施工期间已经可以用于运输工人。这些电梯配有一个临时机房，随着建筑变得越来越高，该机房可以沿着井道逐层向上移动 (即“跃层”) 。相比外部施工升降机，跃层电梯可以提供更高的提升速度，从而提高输送能力和缩短等待时间。因此，跃层电梯可以减少因等待运输而损失的时间。本文介绍了一种计算施工现场垂直运输过程中所损失时间的方法。计算结果显示了工作班次和位置安排会如何影响垂直运输的效率。

关键词: JumpLift (跃层) 电梯、建筑施工期间使用、客流量分析

Introduction

Traditionally, construction hoists are used for vertical transportation of materials and workers on construction sites. However, the early use of permanent elevators provides many advantages for the builder, of which the savings in construction time result in reduced capital and labor cost (Lam et al. 2001). In addition, fewer construction hoists are needed for the project, which decreases the builder's rental costs. Elevators used during construction time are converted into permanent elevators at the end of the construction project by reusing many elevator components, which also reduces the installation time of the elevators.

JumpLift is a special elevator concept for construction time use. It has a temporary machine room, which is raised in jumps as the building itself grows. Thus, JumpLift is capable of serving all floors up to the topmost level below the temporary machine room location. In addition, JumpLift provides the same level of safety and operational efficiency as normal passenger elevators. The operational efficiency is a result of several factors, such as automatic doors with safety edges, and an

引言

传统上，施工升降机用于施工现场材料和工人的垂直运输。然而，在施工初期使用永久性电梯可为建筑商带来许多好处，其中包括节省施工时间，进而降低资本成本和人工成本 (Lam等人，2001年) 。此外，使用电梯还可减少项目所需的施工升降机数量，从而降低了承建商的租金成本。通过再利用许多电梯部件，建筑施工期间所使用的电梯在施工项目竣工后可以转化为永久电梯，因此也缩短了电梯的安装时间。

通力JumpLift电梯是一种特殊的电梯概念，专用于建筑施工期间使用。JumpLift电梯配有一个临时机房，随着建筑本身高度的增长，该机房可以沿着井道向上移动 (即“跃层”) 。因此，JumpLift电梯能够为临时机房位置下面的所有楼层提供垂直运输服务。此外，JumpLift电梯还提供与正常客运电梯一样的安全水平和运行效率。运行效率会受到多种因素的影响，如带安全边缘的自动门以及自动控制系统等。自动控制系统使电梯能够顺畅地运行到召唤楼层，而施工升降机则需要人工操作员。JumpLift电梯的额定速度可以达到4米/秒，而施工升降机的速度一般为0.5-0.7米/秒，在特殊应用中也仅可达到1.6米/秒。另外，JumpLift电

automatic control system, which runs the elevators smoothly to call floors while construction hoists require on board attendants. JumpLifts can have rated speeds up to 4 m/s compared to the construction hoists' typical speeds of 0.5–0.7 m/s, but in special applications 1.6 m/s. Elevators also have higher acceleration values of 0.8–1.2 m/s^2, whereas the acceleration of construction hoists is typically only 0.6 m/s^2.

The traffic flow during construction time of a high-rise building follows similar trends as found in office buildings. There is an up-peak in the morning, when workers need transportation to their workplaces, increased usage before and after lunch time, and down-peak in the evening when the workers end their shifts (Lee et al. 2000, Perttula et al. 2006). While construction hoists are mainly used for transportation between ground level and the topmost floor, JumpLifts are often also used for transportation to other floors below the top floor (Lee at al. 2000). The well-known elevator traffic planning practices can also be applied when analyzing peak performance of construction time elevator use (e.g. Barney 2003). The same method is valid for both the construction hoists and JumpLifts. The difference comes in the higher rated speed and faster doors of the elevators.

Jumplift Principle

JumpLift may be defined as "builder's elevator for construction time use" in addition to "permanent elevator for end-users". Unlike the traditional construction hoist, which is installed on the outer wall, JumpLift is installed inside the permanent elevator hoistway, which is protected against weather conditions. Thus, JumpLift enables safe and reliable transportation at all times. It is designed either to provide additional capacity for workers or to replace construction hoists in cases where the building design does not allow outer wall installations.

JumpLift is a traction drive system using suspension wire ropes, which is installed in stages in an enclosed elevator hoistway as the building "grows taller." JumpLift provides smooth vertical transportation for workers and small tools as the floors served are extended upwards with the progress of the building. As soon as the permanent hoistway has reached the height that it can be waterproofed, the builder installs a deflection crash deck (see Figure 1). The permanent guide rails are installed, along with the core structure, all the way to the top. A second crash deck needs to be installed in line with the jump plan, which defines the number of floors for each "jump". This waterproof protection deck needs to be in place before removing the deflection crash deck, after which the JumpLift can rise in the newly built hoist way section. Below the crash deck sits the working deck that contains the plumbing template of the guide rails and a material hoist. From this deck is suspended the Installation Platform (IT platform), which is used to drive up the installation of the guide rails and other elevator shaft components in the newly opened up shaft space. Once these guide rails are in place, the cathead can move up to its new location higher up in the shaft. The cathead is a temporary fixed machine room that will rise up ("jump") as the building progresses. The elevator controls and the traction machine are located on the cathead.

Below the cathead, the permanent elevator is installed for construction time service, with its actual components such as sling, counterweight and all that is required for safe operation. The elevator cabin, short of its final decoration, is the actual cabin that will be used when the building is finished. Usually, the hoist rope drums are installed on the ground floor although alternative locations are possible if the building design requires this. These rope reels are used throughout the construction

梯还提供更高的加速度，可达0.8-1.2米/秒^2，而施工升降机的加速度一般仅为0.6米/秒^2。

高层建筑施工期间的客流量特点与办公楼的客流量特点相似。早上会出现一次上行客流高峰，这时工人们需要乘坐电梯抵达他们的施工现场; 午餐前后，电梯使用会增加; 晚上则会出现一次下行客流高峰，这时工人们结束工作 (Lee等人，2000年; Perttula等人，2006年)。虽然施工升降机主要用于地面与最顶层之间的运输，但JumpLift电梯也经常用于地面与顶层下面其他楼层之间的运输 (Lee等人，2000年)。分析建筑施工期间电梯使用的最佳性能时 (例如Barney，2003年)，也可以采用众所周知的电梯客流量规划方法。同样的方法对施工升降机和JumpLift电梯均适用。区别在于更高的额定速度和更快的电梯门开关速度。

JUMPLIFT电梯工作原理

除了"供最终用户永久性使用的电梯"之外，JumpLift电梯还可以定义为"供建筑工人在施工期间使用的电梯"。不同于安装在外墙上的传统型施工升降机，JumpLift电梯安装在永久的电梯井道内，可以避免各种天气状况带来的影响。因此，JumpLift电梯始终能够提供安全、可靠的运输，不仅可用于为建筑工人提供额外的运输能力，还可在建筑设计不允许在外墙上安装施工升降机的情况下取代施工升降机。

JumpLift电梯是一种采用悬吊钢丝绳的曳引驱动系统，随着建筑"不断长高"，将其分阶段安装在封闭的电梯井道里。当所服务的楼层随着建筑施工的进展向上延伸时，JumpLift电梯可为工人提供顺畅的垂直运输服务和小型建筑工具。一旦永久性井道到达可以防水的高度，建筑工人就可以安装一个防坠落偏转平台 (见图1)。永久性导轨连同核心结构一起安装，直到顶层。第二个防坠落平台需要根据跃层计划安装，该计划定义了每次"跃层"的楼层数量。这个防水保护平台需要在拆除偏转防坠落平台之前安装到位，然后，JumpLift电梯可以上升到新建成的井道部分。防坠落平台下面安装的是工作平台，其由导轨管道模板和物料升降机组成。悬吊在这个平台上的是安装平台 (IT平台)，其用于向上推动导轨和其他电梯井道部件在新开拓的井道空间内的安装。一旦这些导轨安装到位，吊锚架就可以向上移动到井道内更上方的新位置。吊锚架是一个临时安装的机房，随着建筑施工的进展，不断向上移动 (即"跃层")。电梯控制装置和曳引机均位于吊锚架上。

永久电梯安装在吊锚架下方，供建筑施工期间使用，包括电梯的实际部件，如吊索和配重系统，所有部件均需要安装，以确保安全运行。电梯轿厢 (不包含最终装饰) 是建筑竣工后将使用的实际轿厢。通常情况下，曳引钢绳卷筒都安装在底层; 如果建筑设计

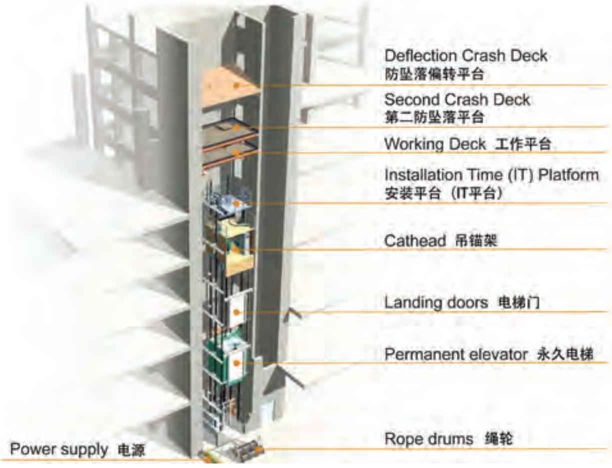

Figure 1. Components of JumpLift (Source: KONE)
图1. 通力JumpLift电梯部件 (来源: 通力)

to 'feed' the rising elevator the exact amount of roping needed to travel correctly and safely. As the core of the building moves upwards, the crash deck is installed by the builder a number of floors up. The working deck is prepared and the IT platform moves up to install the necessary shaft equipment. Then the cathead self-propels itself upward and extends the range of floors served up until the building is finished.

When the core construction is terminated, all that remains to finish the elevator installation is to install the permanent machine room and the final aesthetics for the elevator car, doors and signalization. Since the elevator has been used extensively during the construction, testing can be reduced to a minimum. Inspection and commissioning by the proper authorities is straightforward, as the elevator has been code checked after each jump. In the conversion from JumpLift to permanent elevator, all major components can be utilized, which also reduces the time required to install the final elevator.

Elevator Traffic Analysis for Construction Time Use

Elevator Roundtrip Time Calculation

At a building construction site, the highest demand for vertical transportation of workers occurs at the beginning and the end of the working shifts, as all the workers of the shift require transportation either to or from their workplace. These traffic patterns are known as up-peak and down-peak in elevator traffic planning. For up-peak, an analytical formula has been used for a long time to model elevator roundtrip time (RTT), in which an elevator loads passengers on the ground floor, transports them to their destinations, and returns empty to the ground level (Barney 2003). Several elevators serving the same upper floors are usually combined into an elevator group, for which two important design parameters, handling capacity (HC) and interval (INT), are calculated using the roundtrip time. Handling capacity determines the quantity of service and is usually expressed in passengers per five minutes. The average interval between subsequent elevator starts is INT, on the other hand, which correlates with passenger waiting times. These high-level design parameters are calculated with the equations shown below, where L denotes the number of elevators in the group and P the number of workers transported in one elevator.

$$HC = LxP/RTT$$

$$INT = RTT/L$$

Elevator roundtrip time can be divided into three main components: the time to travel from the ground to the reversal floor at full speed, the time spent during stops, and the time required by the P passengers to transfer in and out of the elevator. The stopping time of the elevator contains delays due to the door and its safety device operation as well as the lifting machinery and its brake. The effect of acceleration and deceleration of the elevator is also taken into account in the stopping time. Usually, the passenger transfer time is rather short for passenger elevators, for example, in total two seconds for one passenger journey (one second for entry, one second for exit). The transfer time of goods is much longer, typically up to 10 seconds although even 30-second transfer times may occur. Roundtrip time is always related to the current construction phase, during which the elevator serves N floor levels above the ground and the total travel height is h meters between the ground and the highest level. In addition to the number of served floors and the number of transported passengers, the distribution of workers (population) on the upper floors affects

要求的话，也可选择其他位置。这些钢绳卷筒在整个施工期间都会使用，用于向正在上升的电梯"补偿"适当、安全运行所需的准确钢丝绳长度。随着建筑的主要结构向上移动，建筑工人会将防坠落平台向上移动一些楼层后安装到位。然后，将工作平台搭建好，将安装平台向上移动，以安装必要的井道设备。接着，吊锚架会自行向上推进，并将所服务的楼层范围向上延伸，直到建筑竣工。

当主要施工结束后，要完成电梯安装还需要进行的是，安装永久性机房，并完成电梯轿厢、电梯轿门和信号装置的最后装饰。由于电梯在建筑施工期间一直广泛使用，因此，可以将测试需求减少到最低限度。相关机构进行的检查和调试非常简单，因为每次跃层后，均根据各种标准对电梯进行了检测。在将JumpLift电梯转换为永久电梯时，所有主要部件均可再利用，这也缩短了最终电梯所需的安装时间。

建筑施工期间的电梯流量分析

电梯往返时间的计算

在建筑施工现场，工人的最大垂直运输需求一般出现在工作班次开始和结束时，因为该班次的所有工人都需要前往或离开他们的工作现场。在电梯客流量规划中，这些流量模式也称为上行高峰和下行高峰。对于上行高峰，有一种分析公式已经使用了很长时间，用于建立电梯往返时间 (RTT) 模型。在这个模型中，电梯在底层装载乘客，将他们运输到各目的楼层，然后空载返回到底层 (Barney，2003年) 。通常会将服务同一楼层的多台电梯组合成一个电梯群组。对于该电梯群组，采用往返时间来计算两个重要设计参数——运输能力 (HC) 和间隔时间 (INT) 。运输能力将决定服务数量，通常以每五分钟运输的乘客数量来表示。另一方面，后续电梯启动的平均间隔时间称为INT，与乘客等待时间相关。这些高层次的设计参数采用下面所示的等式来计算，其中，L表示电梯群组中电梯的数量，P表示一台电梯运输的工人数量。

$$HC = LxP/RTT$$

$$INT = RTT/L$$

我们可以将电梯往返时间分为三个主要部分: 以全速从底层运行到换向楼层的时间、停靠各目的楼层花费的时间以及P名乘客进出电梯所需的时间。电梯的停靠时间包含因电梯门和安全设备运行以及升降机械及其制动器而导致的延误时间。另外，计算停靠时间时，我们还需要考虑电梯加速和减速的影响。通常情况下，对于客运电梯而言，乘客进出时间非常短，例如，一名乘客在整个进出过程中总共花费2秒钟 (进入电梯花1秒钟，离开电梯也花1秒钟) 。而货物的进出时间则长得多，通常多达10秒钟，有时候甚至可能需要30秒钟。电梯往返时间始终与当前的施工阶段相关，在此期间，电梯服务于底层以上的N个楼层，底层与最高楼层之间的总行程为h。除了所服务楼层的数量以及所运输乘客的数量之外，工人 (人口) 在底层以上楼层的分布情况也会影响往返时间模型中的统计数量，即平均换向楼层高度H和平均停靠次数S。

如果建筑内工人 (总人口，POP) 的数量是已知的，运输能力也将决定建筑装满时间 (FT) 。合计电梯将所有工人运输到建筑内需要往返的次数$N_{RTT} = POP / P$。在特殊的往返运行中，所服务乘客的等待时间总是比前一次往返中所服务乘客的等待时间多出一段间隔时间TNT。如果第一组P名乘客的等待时间为零秒钟，那么，最后一组运输的工人的等待时间将为$(N_{RTT} – 1) x INT$。总等待时间 ($WTtot$) 和平均等待时间 (AWT) 可以通过等差数列规则计算得出。最后，一名乘客的平均行程时间 (AJT) 包含等待时间和电梯内的运输时间。

the statistical quantities modeled in the roundtrip time, namely, the average reversal floor H and the average number of probable stops ***S***.

The handling capacity also determines the building filling time (***FT***) if the number of workers (the total population, ***POP***) in the building is known. It takes in total $N_{RTT} = POP / P$ elevator roundtrips to transport the whole population into the building. The waiting time of passengers served in a particular roundtrip is always INT longer than the waiting time of those served in the previous roundtrip. If the first P passengers wait zero seconds, the waiting time of the last transported workers becomes $(N_{RTT} - 1) \times INT$. The total waiting time (***WTtot***), and average waiting time (***AWT***) can be derived using the rule for the sum of arithmetic series. Finally, the average journey time of a passenger (***AJT***) includes the waiting time and the transit time inside an elevator.

$$FT = POP/HC$$

$$WT_{tot} = (N_{RTT} - 1) \times N_{RTT} P/2$$

$$AWT = (N_{RIT} - 1) \times INT/2$$

$$AJT = AWT + RTT/2$$

Population Distribution within a Working Zone

During construction time, the building is likely to be more ready at the bottom than at the top, which causes the population to concentrate at the top. The effect of worker concentration on JumpLift performance is illustrated in three different scenarios for a building with 10 floors above the ground floor (see Figure 2).

Even Worker Distribution

Workers are distributed uniformly among the upper floors (100 workers per floor).

Zoned Worker Distribution

Workers are distributed uniformly between floors 6 and 10 (200 workers per floor).

Triangular Worker Distribution

The number of workers increases linearly with respect to the floor level (10 workers on floor 1, 190 workers on floor 10).

Worker Arrival Patterns

The beginning and the end of the working shift causes peak demand for vertical transportation, as the workers arrive at or leave the site. The average waiting time of the workers can be decreased by increasing the number of JumpLifts and/or construction hoists. However, a less costly way to reduce waiting is to plan the arrival and departure times of the workers properly. The average waiting time is deduced for three examples of arrival profiles (see Figure 3).

All at Once Profile (A)

All workers arrive at the same time in the morning: the first P passengers wait for zero seconds, the next group of P persons waits for INT seconds, and the last transported workers (NRTT - 1) · INT seconds. The average waiting time of a worker for the total population POP with NRTT round trips and P persons is $AWTA = (NRIT - 1) \times INT/2$.

Staged Profile (S)

The arrivals of the workers are split in two stages. The first half of the workers arrives in the morning at the same time as in (A). The second half arrives only after time $N_{RTT} \times INT / 2$ when the first half has been transported. Since only half of the population demand transportation at the same time, the number of roundtrips to transport

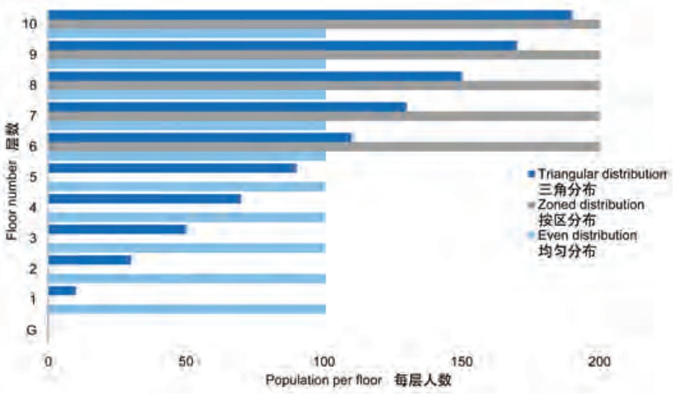

Figure 2. Distribution of population within the working zone (Source: KONE)
图2. 工作区域内的人口分布 (来源: 通力)

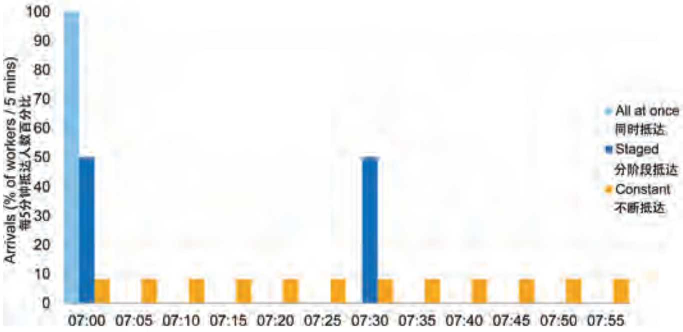

Figure 3. Three arrival profiles: workers arrive all at once, in two stages, or constantly within one hour (Source: KONE)
图3. 三种抵达情形示例: 所有工人同时到达、分为两个阶段到达或者在一个小时内不断到达 (来源: 通力)

$$FT = POP/HC$$

$$WT_{tot} = (N_{RTT} - 1) \times N_{RTT} P/2$$

$$AWT = (N_{RTT} - 1) \times INT/2$$

$$AJT = AWT + RTT/2$$

工作区域内的人口分布

建筑施工期间，建筑可能在底层做好了更多的准备，而不是顶层，这导致人口都集中在顶层。我们描述了在一座地面以上有10个楼层的建筑内，在三种不同的情景下，工人集中度对JumpLift电梯性能的影响 (见图2) 。

工人均匀分布

工人均匀地分布在上面的各个楼层中 (100名工人/层) 。

工人按区分布

工人均匀地分布在第6至第10层 (200名工人/层) 。

工人呈三角分布

工人数量相对于楼层呈线性增加 (1楼有10名工人，10楼有190名工人) 。

工人抵达模式

工作班次开始和结束会引起垂直运输需求高峰，因为工人们需要抵达或离开各施工现场。通过增加JumpLift电梯和/或施工升降机的数量，我们可以缩短工人的平均等待时间。然而，一种成本更低的缩短等待时间的方式是，合理地规划工人的抵达和离开时间。以三种抵达情形为例，我们推导出了平均等待时间 (见图3) 。

them reduces to half of the original. Therefore, also the average waiting times is halved $AWT_S = (N_{RIT}/2 - 1)\ x\ INT/2$.

The staged arrangement does not affect the total filling time if the latter stage starts exactly $N_{RTT}\ x\ INT / 2$ after the first one starts. Naturally, the working time of the second stage workers ends $NRTT\ x\ INT / 2$ later than the first stage.

Constant Profile (C)

Workers arrive at the elevator lobby, at even intervals, so that they do not form a queue longer than the elevator capacity. In this case, the average waiting time becomes half of the interval, since the first worker for a particular elevator start arrives immediately after the previous elevator has left and the last worker walks directly into the elevator without waiting $AWT_C = INT/2$.

In this extreme case, the average waiting time becomes the shortest of these profiles, although constant arrivals are rather challenging to arrange in practice.

Traffic Analysis Example

An example traffic analysis for the up-peak situation, with the three population distributions within the working zone, and with the three arrival profiles is described. The building has reached the height of 10 floors (above the ground) with 3.3 m floor-to-floor distance. Two JumpLifts are in operation, each of which can transport a maximum 21 persons at rated speed of 2.5 m/s. In the beginning of the shift, 1000 workers need to be transported to their workplaces.

The calculation assumes 80% car loading on average (P = 16.8), which is possible to reach if the workers do not carry many tools. By rounding to an even number of 16 passengers, the elevators make roughly 63 round trips (NRTT) to transport all workers up to their floors. The results show that the population distribution does not much affect the average reversal floor, but large variations occur in the average number of stops (see Table 1). As a result, the elevators are able to make one additional roundtrip in five minutes in the best case ("zoned distribution") compared to the worst case ("even distribution") with the shortest filling times. Furthermore, the difference in the filling time is about 15 minutes in these extreme cases. Average waiting times are the shortest for the constant arrivals and the longest when all workers arrive at the same time.

Time Savings During Construction Project

The up-peak based traffic analysis enables the comparison of different vertical transportation solutions for the desired construction time. The comparison is based on the total time a worker spends in vertical transportation daily, which equals the average journey time (**AJT**) of each transport, multiplied by the average number of daily transports per worker (n_{WT}) and the total number of workers (**POP**). Typically, a worker needs four trips per shift (n_{WT}) for vertical transportation: one upward trip in the morning, one downward trip and one upward trip during lunch time for downwards and upwards travels, and finally one downward trip in the evening. For simplicity, the same average journey time is assumed for the down-peak traffic and for the up-peak traffic, although elevator group control makes the handling of down-peak more efficient than up-peak. Thus, the total journey time of workers during one day equals $TJT = AJT\ x\ n_{WT}\ x\ POP$.

所有工人同时抵达 (A)

所有工人早上同时抵达: 第一组P名乘客等待零秒钟，下一组P名乘客等待INT秒钟，最后运输的一组工人等待 (NRTT – 1) · INT秒钟。对于总人口POP及NRTT次往返行程和P名人员来说，一名工人的平均等待时间为: $AWTA = (NRIT - 1)\ x\ INT/2$.

分阶段抵达 (S)

工人们分为两个阶段抵达。前一半工人早上同时在 (A) 时间抵达。当前一半工人被运输到施工现场后，后一半工人在$N_{RTT}\ x\ INT / 2$时间后抵达。由于只有一半的工人需要同时运输，因此，运输他们的往返次数减少到原来的一半。因此，平均等待时间也减少一半: $AWT_S = (N_{RIT}/2 - 1)\ x\ INT/2$.

如果后一阶段的运输在第一阶段的运输开始$NRTT\ x\ INT / 2$时间后准时开始，分阶段安排将不会影响总装满时间。当然，第二阶段运输的工人的工作时间将比第一阶段运输的工人晚$NRTT\ x\ INT / 2$时间后结束。

不断抵达 (C)

工人们按均匀的时间间隔抵达电梯大堂，因此他们不会形成一个超出电梯容量的等待队列。在这种情况下，平均等待时间变为间隔时间的一半，因为对于一次特殊的电梯启用来说，第一名工人会在上一台电梯离开后立即抵达，而最后一名工人将直接走进电梯，无需等待。$AWT_C = INT/2$.

在这种极端情况下，平均等待时间将成为这三种情形下最短的，但不断抵达模式在实践中安排时非常具有挑战性。

客流量分析示例

下面将描述一个上行高峰情况下的客流量分析示例，在这个例子中，工作区域内有三种人口分布模式，并且有三种抵达情形。建筑已经到达10层的高度 (地面以上)，层间距为3.3米。两台JumpLift电梯已投入运行，其中每台电梯在2.5米/秒的额定速度下，最多可以运输21名乘客。在工作班次开始时，需要将1000名工人运输到他们的工作场所。

该计算假设使用80%的轿厢平均载重 (P=16.8)，如果工人不携带许多工具，这是可以实现的。将平均核载人数四舍五入为一个偶数，即16名乘客，这样，电梯大约需要完成63次往返运行 (NRTT)，才能将所有工人运输到他们的目的层。结果显示，人口分布对平均换向楼层的影响并不大，但平均停靠次数出现很大的变化 (见表1)。因此，相比最糟糕的情况 ("均匀分布")，在最好的情况下，电梯能够在五分钟内完成一次额外的往返运行，并且装满时间最短。此外，在这些极端情况下，装满时间的差异大约是15分钟。在工人不断抵达的情况下，平均等待时间最短，而在所有工人同时抵达电梯大堂的情况下，平均等待时间最长。

项目施工期间可节省的时间

Population Distribution 人口分布	H (floor)	S (number)	RTT (s)	HC (p / 5 min)	FT (min)	AWTA (min)	AWTS (min)	AWTC (min)
Even 均匀分布	9.79	8.3	138.4	72.8	69	35.7	17.9	1.2
Zoned 按区分布	9.97	4.9	110.0	91.6	55	28.4	14.2	0.9
Triangular 三角分布	9.97	7.2	130.1	77.5	64	33.6	16.8	1.1

Table 1. Results of the traffic analysis of the example with two JumpLifts (Source: KONE)
表1. 两台通力JumpLifts电梯的客流量分析结果 (来源: 通力)

Phase 阶段	Top floor 最高楼层	HCHoist (p / 5 min)	HCJumpLift (p / 5 min)	TJTHoist (hours)	TJTJumpLift (hours)	Saved working time 节省施工时间 (hours)
1	25	51.9	80.8	3531.5	2268.8	1263.7
2	50	40.3	62.7	4555.0	2924.8	1630.2

Table 2. Working time savings per day if four JumpLifts are used instead of four construction hoists (Source: KONE)
表2. 以四台通力JumpLift电梯取代四台建筑升降机，每天可节省的工作时间 (来源: 通力)

The total journey time per day easily extends to evaluate the time savings of JumpLift and construction time use elevators with respect to the traditional construction hoists. For each day in operation, the total journey time is calculated using the topmost served floor of the elevators and number of workers. To demonstrate the savings in working time, an example calculation is conducted for two phases of a construction project: in the first phase, the top floor is the 25th with a total travel distance of 90 meters and in the second phase the 50th floor with total travel distance of 180 meters. In both phases, 1000 workers are transported between the ground and 25 upper floors. In addition, an even distribution of workers on the upper floors and the all-at-once arrival pattern are used in these calculations. Here, four construction hoists are compared with four JumpLifts, both of them transporting at most 21 persons per car. The construction hoists have a rated speed 1.6 m/s and acceleration of 0.6 m/s^2, while JumpLifts have 2.5 m/s and 0.8 m/s^2, respectively. In this case, the handling capacity with JumpLifts is about 50% greater than with construction hoists (see Table 2). Then, filling time and total journey time are about 50% longer with construction hoists than with JumpLifts. This immediately implies considerable time savings due to efficient vertical transportation, which even increases as the building gets higher.

Conclusion

This paper introduced the principle of JumpLift and traffic analysis suited for construction time use of elevators. The analysis was applied for different worker distributions on the upper floors and arrival patterns during peak times. These factors greatly affect the vertical transportation and the time the workers need to spend in it. The presented scenarios give hints about how the work on the construction site could be arranged to make the vertical transportation as efficient as possible. The traffic analysis was extended to cover the whole duration of the construction project to show the time savings achieved by using elevators during construction time instead of construction hoists. The improved site logistics with elevators has the potential of reducing the total project duration by several months, which gives rise to significant savings in reduced labor costs for the builder and in reduced capital costs for the investor.

基于上行高峰的客流量分析能够对建筑施工期间的不同垂直运输解决方案进行比较。该比较基于一名工人每天花费在垂直运输上的总时间[其等于每次运输的平均行程时间 (AJT) 乘以每名工人每天的平均运输次数 (n_{WT})]和工人总数 (POP) 来进行。通常情况下，一名工人每个班次需要经历四次垂直运输: 早上一次向上行程、午餐时间一次向下行程和一次向上行程以及晚上最后一次向下行程。虽然电梯群控系统会使下行高峰的运输比上行高峰的运输更高效，但为了简单起见，我们假设下行高峰与上行高峰的平均行程时间相同。因此，工人们每天的总行程时间等于: $TJT = AJT \text{ x } n_{WT} \text{ x } POP$.

根据每天的总行程时间，我们很容易评估相比传统的施工升降机，建筑施工期间使用JumpLift电梯能够节省的时间。对于投入运行的每一天，我们可以采用电梯所服务的最顶层和工人数量来计算总行程时间。为了证明所实现的工作时间节省，我们以一个施工项目的两个阶段为例进行了计算: 在第一阶段，最顶层为25楼，总行程距离为90米; 在第二阶段，最顶层为50楼，总行程距离为180米。在这两个阶段，都需要在底层与25层之间运输1000名工人; 此外，在这些计算中，我们假设的模式是，工人在上面各楼层均匀分布，并且全部同时抵达电梯大堂。在此，我们将四台施工升降机与四台JumpLift电梯进行了比较，这两种设备的轿厢均最多可装载21名乘客。施工升降机的额定速度为1.6米/秒，加速度为0.6米/秒2，而JumpLift电梯的额定速度和加速度分别为2.5米/秒和0.8米/秒2。在这种情况下，JumpLift电梯的运输能力比施工升降机大约高50% (见表2) 。并且，施工升降机的装满时间和总行程时间比JumpLift电梯大约长50%。我们立即可以看出，JumpLift电梯凭借高效的垂直运输节省了大量时间，并且随着建筑变得越来越高，所节省的时间还会增加。

结论

本文介绍了通力JumpLift电梯的工作原理以及适用于建筑施工期间的电梯流量分析方法。该分析涉及了工人在各楼层的不同分布模式以及客流量高峰期间不同的抵达模式。这些因素会极大地影响垂直运输以及工人需要花费的时间。本文所介绍的各种情景显示了如何安排施工现场的工作，以确保垂直运输尽可能高效。另外，本文还进一步拓展了客流量分析，涵盖了建筑项目的整个工期，以显示施工期间采用JumpLift电梯取代施工升降机可以实现的时间节省。采用JumpLift电梯改进施工现场物流后，项目总工期可以缩短多达数个月，从而显著地降低了承建商的人工成本以及投资商的资本成本。

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