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Use of Elevators During Emergencies

紧急情况下电梯的使用

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Abstract

This paper explores evacuation improvement opportunities achieved through interoperation of various systems in tall buildings. Tall buildings comprise many highly intelligent systems that can be interconnected to provide an efficient and versatile means to evacuate occupants in the event of a fire or other threat condition. The systems that will be discussed include: fire alarm; elevator; security; heating, ventilation and air conditioning (HVAC); lighting; and emergency power systems. The notion of an evacuation controller will be explored as a means to coordinate these systems. Additionally, the concept of a content server and command center will be discussed to assist occupants and first responders. A rich set of networked sensors and audio/video devices will be "repurposed" during evacuations to provide a cost-effective solution. This paper also explores aspects of human behavior during emergencies and discusses methods to model and predict threat propagation to control people flow.

Keywords: Evacuation Controller, Content Server, Command Center, OEO, Risk Measure

摘要

本文探讨的是如何通过高层建筑各系统间交互操作提高疏散效率。高层建筑包括许多高度智能系统，这些系统之间相互连接，当发生火灾或者遇到其他危险时，帮助楼内人员快速、高效地完成疏散。在本文中将会讨论的系统包括: 火警、电梯、安防、暖通空调、照明以及应急电源系统。疏散控制器将作为协调这些系统的一种手段进行探讨。此外，还将讨论服务器和指挥中心如何对楼内人员和现场急救员提供帮助。在疏散时，还将"重新利用"一套复杂的网络传感器和音频/视频设备，提供一种经济的的解决方案。本文还探讨了人们在发生紧急事件时的各种行为，并且讨论模拟和预测当危险蔓延时控制人流的方法。

关键词: 疏散控制器、服务器、指挥中心、楼内人员疏散操作、危险控制

Introduction

The advent of super high-rise buildings in the 21st century has given rise to renewed interest in the safe handling of occupants in an emergency situation. As learned from the catastrophic events of Sept. 11, 2001, it is of paramount importance to evacuate people from tall buildings in an efficient and timely manner. Based on numerous studies and simulations, it has been shown that the addition of elevators to evacuate occupants can substantially reduce the time versus evacuation by stairs exclusively (CTBUH 2004 & SFPE 2012). This paper describes the current status of the use of elevators for building evacuation and explores opportunities to enhance evacuation through an objective-based approach and greater interconnectivity of intelligent building systems.

Associated Research and Publications

There is an extensive body of research published in the field of study of using elevators for occupant evacuation. In one

简介

二十一世纪超高层建筑的不断出现向人们提出了一个全新的课题，即: 当发生紧急情况时，如何安全疏散楼内人员? 2001年9月11日的灾难性事件使我们认识到，及时高效地疏散高层建筑中的人群是多么重要。大量研究和模拟结果显示，相对于完全利用楼梯疏散来说，增加电梯的使用可能会大幅减少疏散时间 (CTBUH 2004 & SFPE 2012)。本文介绍了如何使用电梯进行人员疏散，并探讨了如何通过以疏散人员为目标和提高智能建筑系统的互连性来提高疏散效率。

相关研究和出版物

大量研究机构发表了各种研究成果阐述如何利用电梯进行人员疏散。在一篇文章中 (Kuligowski 2003)，作者认为应当更好地了解楼内人员的活动情况，厢式电梯和客用电梯的运行情况，起火后的内部环境，以及人们在整个疏散期间的行为。作者得出的结论是: 当利用电梯疏散时，尤其在高层建筑中使用电梯疏散可以缩减疏散时间。

paper (Kuligowski 2003), the author suggested that there is a need to better understand movement of occupants on stairs, elevator movement of both cars and passengers, environmental conditions in the building due to fire and human behavior during the entire evacuation. The author concluded that evacuation time improves when using elevators for evacuation, particularly in tall buildings.

Another paper (Bukowski 2011) contemplated incorporating elevators and escalators into emergency evacuation situations. In this paper, the author discussed the 2009 International Building Code (IBC) and NFPA Building Construction and Safety Code (NFPA 5000) code changes, and the subsequent ASME A17.1 changes that permitted the use of elevators for occupant evacuation. He described the coordination of fire alarm, elevator and emergency (voice) evacuation systems as a means to guide occupants. He also explained the importance of modeling occupant evacuation operation (OEO) to determine total evacuation time for any particular building.

One publication (CTBUH 2004) describes in great detail many aspects of emergency evacuation using elevators. This paper characterized the design approach for elevators, discussed the electrical systems involved in addition to the elevator system and explained the concept of integration using building automation systems. The integrated systems described were security, building automation, intercom or voice annunciation, elevator, emergency power, lighting and fire alarm. The authors stated that total integration of the various systems is not yet attainable, nor perhaps advisable.

Code Changes

As mentioned previously, there are building code changes that permit the use of elevators to evacuate occupants in the event of an emergency. The 2009 IBC and NFPA 5000 permit the use of elevators for occupant self-evacuation in fires. The coordinated requirements, for North America, can be found in the 2013 ASME A17.1/CSA B44 Safety Code for Elevators and Escalators, the 2013 NFPA 72 National Fire Alarm and Signaling Code, and the 2012 NFPA 101 Life Safety codes.

Use of Elevators During Fire Emergencies (ASME A17.1/CSA B44)

A new elevator Occupant Evacuation Operation (OEO) was developed and is included in section (2.27.11) in the 2013 edition of the ASME A17.1/CSA B44 Code. OEO is defined as "the operation of an elevator system for occupant evacuation under emergency conditions" and provides elevator operation from a zone of five affected floors (the fire floor and two floors above and below the fire floor) to a discharge level. OEO is not a mandatory requirement, but the IBC requires that "where elevators are to be used for occupant self-evacuation during fires, all passenger elevators for general public use shall comply with" Section 3008, which contains requirements for "Occupant Evacuation Elevators." Although there is no direct reference to OEO in Section 3008 of the IBC, the IBC requirement would mean that, if provided, OEO would be required on all passenger elevators in a building. OEO would commence automatically in a group of elevators whenever there is a fire alarm signal in a building which does not activate Phase 1 Recall in that group, i.e., activated fire alarm initiating devices (FAID) outside of the elevator lobbies and machine rooms.

If activation of an automatic FAID occurs on an additional floor(s) at any time while OEO is in effect, the evacuation zone is expanded to include

另一篇文章 (Bukowski 2011) 讨论的是电梯和自动扶梯进入紧急疏散状态之后的情况。作者讨论了2009年国际建筑规范 (IBC) 和NFPA建筑构造和安全规范 (NFPA 5000) 的规范修改以及后续的ASME A17.1的修改，修改后的规范允许利用电梯进行人员疏散。作者把火警、电梯和紧急 (声音) 疏散系统的相互配合作为引导楼内人员疏散的一种手段。文中还说明了楼内人员疏散操作(OEO)模拟对确定特定建筑进行人员疏散所用时间的重要性。

出版物 (CTBUH 2004) 极其详尽地描述了利用电梯执行紧急疏散的诸多细节。该文章讲述了电梯的设计方法，还讨论了相关的电气系统，并且阐述了如何利用建筑自动化系统进行整合。所述的整合后系统包括安防、建筑自动化、对讲或语音通信、电梯、应急电源、照明和火警系统等。作者阐明，至今仍未能将各种系统完全整合起来，或许，这不是一种可取的方法。

修改规范

根据前述，诸多建筑规范已被修改，修改后的新版本允许在发生紧急情况时利用电梯进行人员疏散。2009 IBC和NFPA 5000 允许在发生火灾时楼内人员可以利用电梯进行自行疏散。在北美地区，2013 ASME A17.1/CSA B44"电梯和自动扶梯的安全性规程"和2013 NFPA 72"国家火警及信号规范"以及2012 NFPA 101"生命安全规范"中可以找到经调整后的说明要求。

发生火灾时如何使用电梯 (ASME A17.1/CSA B44)

新的电梯"疏散楼内人员操作" (OEO) 规程已经编制完成，并且纳入ASME A17.1/CSA B44规范2003版的条款 (2.27.11) 中。OEO被定义为"在紧急条件下，为疏散楼内人员而运行电梯系统"，提供的电梯操作可以将五个受影响楼层 (起火楼层及上下各两个楼层) 内的人员运送到逃生地带。OEO不是强制性操作规则，但是IBC规定: "如果电梯用于起火时楼内人员自行疏散使用，所有公用客梯都应遵守"第3008章节的要求，其中包含针对"疏散楼内人员使用电梯"的要求。虽然在IBC第3008章节中未直接提及OEO，但IBC要求意味着，如果提供OEO，则建筑内的所有客用电梯都需要提供OEO。当建筑内任何时间出现火警信号时，即使第一阶段消防服务 (即电梯门厅和机房外部的火警触发装置(FAID)) 没有被激活，也将自动启动一组电梯中的OEO。

当OEO仍然启动的时候，如果在其他楼层触发了自动化FAID，疏散区域将扩展到已启动报警的所有楼层，包含已启动报警的最高楼层到最低楼层，以及启动报警的最高楼层以上的两个楼层，最低楼层以下的两个楼层。

关于整体建筑疏散则有一个选择功能，由授权人员或者应急人员手动触发消防指挥中心的报警。当所有楼层都需要疏散时，火警系统可以将该信号发送给电梯系统。

标识和通信

为方便操作OEO，使楼内人员对新规范进行熟练操作，需要广泛地布置标识，并且需要对租户进行相关培训。当前在电梯门厅内的标识内容为"发生火灾时，电梯停运" (参见图1) 。

具有OEO设计的建筑将不再使用该标识。因此需要设计新的标识内容。在所有楼层将提供实时标牌，使乘客可以随时了解在某一特定楼层的电梯是否可以使用。楼内人员将看到诸如"电梯可用于人员疏散，下一电梯厢将在两分钟左右到达"，"电梯临时专门于其他楼层"或者"电梯停运，请使用楼梯疏散"等信息。

all floors with an active alarm, all floors between the highest and lowest floor with an active alarm plus two floors above the highest floor with an active alarm and two floors below the lowest floor with an active alarm.

There is an option for Full Building Evacuation, manually initiated in the fire command center by authorized or emergency personnel. The fire alarm system provides this signal to the elevator system when all floors are to be evacuated.

Signage and Communications

Extensive signage and tenant training are necessary to facilitate OEO and allow occupants to adapt to this new paradigm. Currently, buildings have a sign in elevator lobbies which reads, "In Case of Fire, Elevators Are Out of Service" (see Figure 1).

This sign will no longer be used in buildings with OEO. A new paradigm in signage is required. Real-time signage will be provided on all floors to inform people whether or not to use the elevators on a given floor. Occupants will see messages such as "Elevators available for evacuation. Next car in about two minutes," "Elevators temporarily dedicated to other floors" or "Elevators out of service. Use stairs to evacuate."

Seeing the estimated time of arrival of an elevator to an evacuation floor will allow occupants to decide if they want to wait or use the stairs. Signage at the main lobby landing will advise people to not use the elevator. Signs in the cars will give passengers instructions to exit the car at the discharge level. Real-time voice announcements to elevator lobbies and cars will supplement elevator signage, and building occupant training and drills will take place. During an emergency, floor wardens will supplement other efforts.

Activation of OEO

When OEO is activated, landing calls outside of the evacuation floors will be cancelled and disabled. Security systems will be overridden. Landing calls on the affected floors will call an elevator to those floors. Floors with an active alarm are given highest priority. At other floors, the evacuation priority will be assigned in the sequence received. Highest floor calls will be given the highest priority in Full Building Evacuation unless there are calls at the affected floors. Car calls are disabled except for a call to the discharge level.

Unoccupied cars will move to a floor being evacuated and park with doors closed until a landing call is registered. Occupied cars proceed directly to the elevator discharge level and then proceed directly to a floor being evacuated. New landing calls are registered immediately and assigned to another car. New landing calls cannot prevent a loaded car from leaving. Cars with 80 percent of load start to close their doors and proceed to the elevator discharge level.

Cars with more than 100 percent load will not leave the floor, their doors will remain open,and a voice and visual notification will inform passengers that the car is overloaded.

After Evacuation

A 60-second period with no registered landing calls indicates that the affected floor was evacuated. At this time, one car will park with its doors closed at the lowest floor of the affected floors, ready to answer

Figure 1. Elevator Corridor Call Station Pictograph (Source: ASME 17.1-2013/CSA B44-13)
图片 1. 电梯等候点示意图标（源引: ASME 17.1-2013/CSA B44-13)

楼内人员能够看到电梯抵达疏散楼层的预计时间，他们可以决定选择等待还是走楼梯。在大厅平台上的标识将用于建议人们不要使用电梯。在轿厢内的标识将指导人门在疏散楼层离开轿厢。面向电梯厅和轿厢的实时语音播报将作为电梯的补充信息，还将对行楼内人员进行培训和演习。当发生紧急情况时，各楼层管理员将辅助楼内人员进行疏散。

OEO的启动

当启动OEO时，疏散楼层以外的调用将被取消和禁用; 安全系统将被取代; 受影响楼层将调用一部电梯通向这些楼层; 报警装置被激活的楼层获得最高优先权。在其他楼层，将按照收到调用的顺序安排疏散的先后顺序。在"全部建筑疏散"时，最高楼层调用将获得最高优先权，除非受影响的楼层发出调用要求。除了向对外疏散楼层的内呼之外，其余轿厢内呼被禁用。

闲置的轿厢将运行到需要疏散的楼层，在收到乘用要求之前，停泊的轿厢门将始终处于关闭状态。使用中的轿厢将直接运行到电梯疏散点，然后直接向其他需要疏散的楼层运行。当收到新的乘用要求后，将立即派遣另一部轿厢。新的乘用要求无法阻止已经有人乘用的轿厢离开。荷载量达到80%的轿厢开始关闭电梯门，然后向电梯疏散点运行。

荷载量超过100%的轿厢将无法离开所在的楼层，电梯将始终打开，并且发出语音和视觉告示，告知乘客轿厢超载。

疏散之后

超过60秒之后如果没有收到乘用要求，表明受影响楼层已经疏散。此时，受影响楼层的最低楼层将停泊一部轿厢，轿厢门保持

subsequent landing calls of remaining evacuees. The rest of the cars park with their doors closed at the elevator discharge level. A car parked at the elevator discharge level will replace the car at the lowest floor of the affected floors which has answered a landing call.

Firefighters will be able to manually recall one or more cars from a group, leaving the rest of the group to continue operating on OEO if needed. Individual car recall is enabled by a new set of Phase 1 Recall switches, one for each car, marked in a yellow and black scheme to distinguish the car recall switches from the traditional group recall switch, marked in red.

If smoke reaches one of the initiating devices normally used to initiate Phase 1 Recall, such as a device in the elevator lobby or in an elevator hoistway or machine room, OEO will be automatically terminated and a Phase 1 Recall will commence. Reset of the fire alarm system will terminate OEO.

Requirements for Buildings with OEO

Building enhancements are necessary to ensure safe use of OEO and part of the proposal developed for in addition to ASME A17.1/CSA B44 Elevator Code includes an appendix on building requirements deemed to be necessary features by a hazard analysis conducted by the A17 Task Group. The A17 Task Group made recommendations to the building code writing organizations to include all of the requirements listed in the OEO appendix. These include:

- Protected lobbies able to accommodate 25 percent of the floor population with direct access to stairwells
- Pressurized hoistways, lobbies and stairwells
- Automatic sprinkler system in conformance with NFPA 13, excluding hoistways and machine rooms ("shunt-trip" also excluded)
- Building smoke detection system
- Voice alarm/communications system in conformance with NFPA 72
- Protected emergency power (two hours) to elevators, signage/voice, pressurization and ventilation systems
- Water flow protection to prevent water from entering hoistways
- Building fire and evacuation plan
  - Procedures for evacuation using stairs and elevators
  - Building occupant training and drills
  - Use of floor wardens
  - Routine integrated testing

Simulation Results for Alternate Evacuation Strategies

Previous Case Studies

There are a number of case studies on the combined use of elevators and stairs for occupant evacuation. A publication (Kuligowski 2003) discussed a firefighter lift case study and an elevator evacuation case study consisting of four General Services Administration buildings. Regarding elevator evacuation, the author concluded that by using a combination of stairs and elevators, the total evacuation time of the building can be reduced by a substantial amount, especially in taller buildings.

关闭，随时等待响应其余逃生人员的乘用要求。其余轿厢停泊在电梯疏散点，轿厢门保持关闭。停在电梯疏散点的轿厢将接替已经对乘用要求作出响应的受影响楼层最低层的轿厢。

消防员应可以手动调用一组轿厢中的一个或多个轿厢，如果需要，使其余轿厢继续在OEO上运行。由一套新的第1阶段召回开关激活个别轿厢的召回，每个开关召回一部轿厢，新的轿厢召回开关使用黄黑条纹标记，以区别于标记为红色的传统成组召回开关。

如果烟雾蔓延到通常用于启动第1阶段召回的启动装置 (此类装置位于电梯厅或电梯井或机房中)，OEO将自动终止运行，并且第1阶段召回将启动。火灾报警系统复位之后，OEO将终止运行。

针对具有OEO设计的建筑提出的要求

为了确保安全使用OEO，需要增强建筑的功能，附属于ASME A17.1/CSA B44电梯规范的已编制方案的一部分包括关于建筑的附件要求，这是A17任务小组执行的一项危险分析的必要方面。A17任务小组建议建筑规范编写组织纳入OEO附件中所列的全部要求。这些要求包括:

- 已采取保护措施的电梯厅能够容纳楼层总人数的25%，并且直接通向楼梯间。
- 受压电梯井、门厅和楼梯间
- 符合NFPA 13规范的自动喷淋灭火系统，不包括电梯井和机房 (也不包括“分流跳闸”)
- 建筑烟雾探测系统
- 符合NFPA 72的语音报警/通信系统
- 电梯、标识/语音、加压和通风系统的防护紧急电源 (2小时)
- 防止向电梯井渗水的挡水保护措施。
- 火灾疏散计划
  - 利用楼梯和电梯的疏散程序。
  - 住户培训和演习
  - 楼层管理员的使用
  - 常规综合测试

备用疏散策略的模拟结果

之前的案例研究

现在已经有许多关于联合利用电梯和楼梯疏散楼内人员的案例研究。有一篇出版物 (Kuligowski 2003) 讨论了消防员电梯案例研究和电梯疏散案例研究，其中涉及四种常规建筑。在电梯疏散方面作者得出结论，通过电梯和楼梯相结合进行人员疏散可以大幅缩减总体疏散时间，尤其是对于高层建筑而言。

另一篇文章 (CTBUH 2004) 研究了当中等层建筑受到炸弹威胁时，或者置身火灾中，对楼内人员进行全体疏散、分阶段疏散和零散疏散等几种情况。当遭受炸弹袭击，对楼内人员进行全体疏散为例所得出的结论是，同时使用楼梯和电梯，疏散时间比仅使用楼梯缩减一半。

基于这些研究结果可以看出，有指挥的的综合使用楼梯和电梯是缩短总体疏散时间的首选方法。

备用人员疏散案例

目前疏散时的电梯操作标准是遵守规则，比如运行一部往来于庇护楼层 (比较典型的是通过加压避免浓烟渗入的楼层) 与出口楼层

Another paper (CTBUH 2004) studied a total, staged and fractional evacuation in a bomb threat and fire scenario for a mid-rise building. The conclusion drawn from the bomb threat scenario using total evacuation was that if both stairs and all elevators were used, the egress time would drop to approximately half of a stairway-only evacuation.

Based on the results of these case studies, it would appear that a controlled use of both stairs and elevators during building evacuation is a preferred method to reduce the total time of egress.

Case for Alternative Evacuation Methods

Current standards follow a rule-based protocol for operating elevators during evacuation, such as operating an elevator as a shuttle between a refuge floor (typically pressurized to prevent smoke infiltration) and an exit floor, or using elevators to evacuate occupants from the floor where the emergency is reported as well as the two floors above and below the threat floor. The typical metric for evaluating these methods is the amount of time to fully evacuate the building.

Instead, six further considerations are proposed for effective evacuation: (1) use an objective-based approach that dynamically searches through a set of alternatives and best prioritizes the floors served by elevators rather than follow a rule-based approach; (2) use a measure of risk to occupants as the main objective rather than evacuation time — there may be strategies that minimize risk by quickly transporting occupants away from the threat areas even though the total evacuation time may be increased; (3) use available information to alter the objective-based approach continuously, including sensing the location of occupants, the spread of the threat and blockage of passageways; (4) use predictive models of people flow and the spread of fire, smoke and other threats to inform the objective-based approach as to the merit of each alternative; (5) use communications, such as signage and transmission to mobile devices that actively and dynamically guide occupants to follow the best egress path; and (6) combine first-responder needs with the evacuation strategy.

An analysis using a stairway pedestrian flow model, elevator model and control model was performed to compare various strategies. As an example, a hypothetical 47-floor building with 24 elevators available for egress and two stairways was studied with a threat event at the 45th floor. The 24 elevators all access the ground floor (floor 1) and are arranged in three elevator groups of eight elevators serving floors 2-15, 16-31 and 32-47. Compared with all other floors, the risk measure per occupant at the threat floor is assumed to be 50 times greater and 25 times greater at the two floors above and two floors below the 45th floor. Three strategies were compared with the goal of minimizing both the risk measure and the evacuation time. The risk measure value is computed by the time (in minutes) spent at each floor in the building multiplied by the risk measure value at that floor, summed for the last evacuee from each floor. The OEO strategy sequentially evacuates the floor population to the ground floor with the following floor priority: floor 45 (threat floor), floors 46 and 47 (floors above the threat floor), and then 44, 43, 42 and so forth (all other floors beginning with the highest floor). In this scenario, the evacuation time was 28 minutes with a total risk measure value of 1,352. By comparison, a second strategy that does not use the elevators results in an evacuation time of 84 minutes and a total risk measure value of 2,003. However, an optimized controlled strategy can reduce the evacuation time to 24 minutes and a total risk measure value of 777 by staging the evacuation to first use elevators to immediately move people away from the high-risk floors (45, 46 and 47) to a safe floor at floor 42 and directing occupants on floors 44 and 43 to take the stairs to floor 42.

之间的穿梭电梯，或者利用电梯疏散那些出现紧急情况楼层的人员，及其上、下两层的人员。典型的衡量标准是疏散全体人员所需的时间。

相反地，为有效疏散人员提出了6个需要进一步考虑的因素是: (1) 以疏散人员为目的，在一套备选项中进行动态搜索，最大程度地优化电梯服务的楼层，而不是墨守规则; (2) 以减少楼内人员危险为目的，而不是以疏散时间度量——这可能是使楼内人员快速离开危险区域从而尽量降低风险的一种策略，即使总体疏散时间可能会所有增加; (3) 利用可用信息不断更改目标的方法，包括了解楼内人员的位置，危险的蔓延程度以及受阻的通道; (4) 利用人员流向、火焰和浓烟蔓延方向以及其他危险情况的预测模型，再告知以疏散人员为目的的优选项; (5) 利用通信工具，比如标牌和转换行动装置，可以主动地、动态地指导楼内人员沿着最佳疏散路径逃生; (6) 急救人员的需求与疏散策略相结合。

利用楼梯人流模型、电梯模型和控制模型进行分析，以比较不同的策略。以一座假设拥有24部疏散电梯以及两部楼梯的47层建筑为例，假设危险发生在第45层，全部24部电梯都通向底层 (1层)，每八部电梯分为一组，共三个电梯组，分别服务于2-15层、16-31层和32-47层。相比其他楼层，假设处于危险楼层的人员风险度为50倍，第45层以上的两个楼层和以下两个楼层的人员风险为25倍。以降低风险和减少疏散时间为目标对三种策略进行比较。每个楼层的最后一名逃离人员所花费的时间 (单位: 分钟) 乘以该楼层的风险值，即为它的风险值。OEO策略依序将各楼层人员疏散到底层，各楼层的先后顺序如下: 45层 (危险楼层) 、46和47层 (危险楼层以上的两个楼层) ，然后是44、43、42，以此类推 (所有其他楼层都从高层开始) 。在此场景中，疏散用时为28分钟，风险总值为1,352。通过对比，不使用电梯的第二种策略的疏散用时为84分钟，风险总值为2,003。如果利用优化的可控策略，通过安排需要疏散楼层的人员优先使用电梯，立即将高危楼层 (45、46和47层) 的人员撤离到第42层的安全楼层，并且指挥第44和43层的人员从楼梯步行至42层，可以将疏散用时减少到24分钟，使风险总值缩减到777。接下来，电梯往返于所选楼层之间，即: 第42层、35层、24层和13层，将这些楼层上的人员输送到底层。该策略指挥第12层及以下楼层的全体人员从楼梯逃生。第14至23层的人将从楼梯跑到第13层，然后，乘电梯至底层，以此类推。注意: 对于无法使用楼梯的人员，比如需要乘坐轮椅的人，则将提供特例。此策略使楼梯和电梯的使用达到均衡，从而实现降低风险和减少疏散时间的目的。

总之，为了减少高层建筑在发生危险时的风险，提高电梯辅助疏散效率仍有很大的改进空间。

智能建筑科技创造未来机遇

机会和考虑因素

除了电梯，高层建筑在疏散人员时还有其他可以利用的设备。这些设备包括火警、安保、暖通空调系统和应急电源系统。关键是这些系统之间应高度整合，成为一种高效、经济的解决方案，同时尽量降低楼内人员和应急救援人员的危险。图2给出了实现这一目标的潜在架构。

图2描绘了不同建筑系统之间的互连。每个系统都具有基于功能和规范要求而明确界定的一套自有要求。在此概念中，疏散控制器用于在发生火灾或其他危险时协调其他建筑系统的响应。在火灾中，控制器以疏散人员为目的，从不同系统获取信息，并利用电梯、暖通空调、安防、通知和照明系统协助楼内人员采用高效、及时的方式撤离建筑。疏散控制器能够利用威胁蔓延预测技术追踪某种危险，并且通知内容服务器，以修改出口标识和语音通知，从而控制即将使用电梯疏散的楼层，调节暖通空调系统，

Next, elevators shuttle occupants from select floors, namely floors 42, 35, 24 and 13, to the ground floor. This strategy directs all occupants on floors 12 and below to evacuate by stairs alone. Occupants on floors 14 to 23 would take the stairs to floor 13 and then take elevators to the ground floor, and so forth. Note that exceptions will be provided for occupants who cannot use the stairs, such as wheelchair users. This strategy balances the use of stairs and elevators to achieve the objective.

In summary, there is potential to significantly improve elevator-assisted evacuation to reduce the risk measure during a threat event in tall buildings.

Future Opportunities through Intelligent Building Technologies

Opportunities and Considerations

In addition to the elevators, tall buildings frequently contain other assets that can be utilized when evacuating occupants. These assets include fire alarm, security, HVAC, lighting and emergency power systems. The key is to provide a high level of interoperability between these systems to achieve an efficient and cost-effective solution while minimizing the risk to occupants and first responders. A potential architecture to achieve this goal is illustrated in Figure 2.

Figure 2 depicts the interconnection of several building systems. Each system has its own set of well-defined requirements based on the functional and code-required objectives. In this concept, the evacuation controller coordinates the response of the other building systems in the event of a fire or other threat. In a fire scenario, it obtains information from various systems and utilizes the elevator, HVAC, security, notification and lighting systems to assist occupants to evacuate a building in an efficient and timely manner using an objective-based approach. The evacuation controller has the ability to track a threat using threat-propagation prediction, to inform the content server to modify the exit signage and voice notification, to control the floor(s) the elevators will evacuate, to adjust the HVAC system to control smoke and provide pressurization, and provide information to the command center to aid the first responders via decision support and control. Additionally, assets normally used for other purposes, such as video cameras and access control, could be repurposed to assist in threat-propagation tracking to provide visual support to first responders and track/record occupants present in a building. Intelligent video analytics can provide queuing metrics, wait-time determination, flow monitoring and wrong-way detection. This information can be utilized by the evacuation controller to optimize performance of the system.

Under the direction of the evacuation controller, the content server can be used for stationary audio/visual message delivery, as well as a resource for mobile devices. The content server is a type of Mass Notification and Emergency Communications (MNEC) system and can be a very useful communication and emergency management tool to provide real-time instructions and information to building occupants during an emergency. MNEC can notify people about an event as to what is happening, what to do, where to go and when it is safe. The way-finding means can be implemented as a sign, map or other graphical or audible method. It can be delivered to fixed signage, audio devices or mobile devices.

Decision support and control, from the command center, provides first responders with a central monitoring station for all alarms generated in a building. To allow for remote access, redundancy, reliability and scalability, a monitoring station could be hosted outside the building.

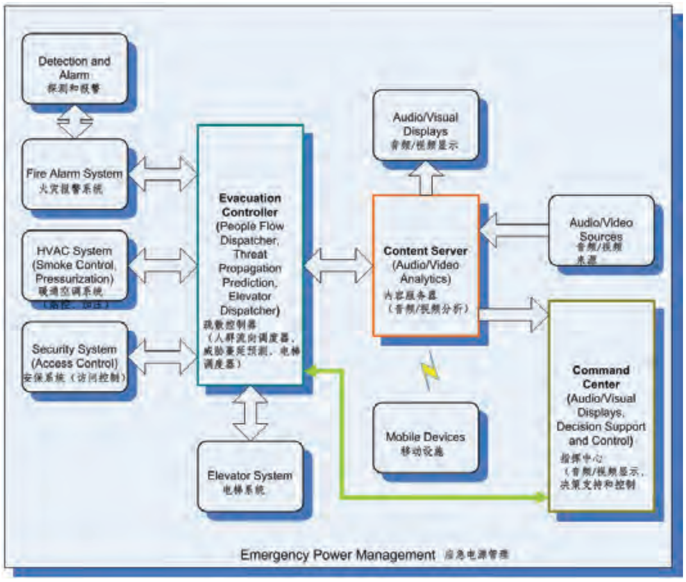

Figure 2. Emergency Power Management
图片 2. 应急电源管理

控制烟雾蔓延，提供加压，向指挥中心提供信息，借助决策支持和控制，为应急救援人员提供帮助。另外，通常用于其他用途的设施，比如摄像机和门禁，也可以重新目的化使用，为威胁蔓延追踪提供支持，为应急救援人员提供视觉支持，以及追踪/记录在楼内的人员。智能视频分析仪可以提供排队情况、等待时间长短、人群流向监控以及检查错误疏散方式等。疏散控制器可以根据这些信息用于优化系统功能。

在疏散控制器的指挥下，内容服务器可以用于传输静态音频/视频信息，并且可以作为移动设备的资源。内容服务器是"公众通知和紧急通信 (MNEC) 系统"的一种类型，并且可成为一种非常有用的通信和紧急情况管理工具，当发生紧急情况时，向楼内人员提供实时指导和相关信息。MNEC系统可以将正在发生的事件、应采取的措施、到何处去，何时到达安全地带等信息告知人们。标牌、地图或者其他图形或音频方式都可以作为寻路工具。利用固定标牌、音频装置或者移动装置可以实现此功能。

来自指挥中心的决策支持和控制功能，为紧急救援人员提供了一个中央监测站，用于监测建筑内生成的所有警报。为了实现远程访问、冗余、可靠性和可扩展性，也可在建筑外部安装一个监测站。

在紧急情况发生期间，所有系统必须保持运行，并有应急发电机或者蓄电池作为后备支持。通过智能建筑系统与监测危险蔓延和人群流向的先进模型的共享信息，可获取楼内人员安全疏散的整体分析。

结论

总之，本文讨论的是在适用规范允许范围内，当高层建筑发生火灾或者其他危险情况时使用电梯和楼梯进行人员疏散。并且讲述了旨在尽量降低楼内人员危险的一种以疏散人员为目的的替代方法。为了支持此方法，研究显示，通过使不同建筑系统实现互连，在疏散控制器的指挥下重复利用各种功能设备协调楼内人员的撤离，进而取得理想的结果。另外，内容服务器可以借助远程访问提供信息，使紧急救援人员在到达指挥中心之前就能够观察到建筑内的状况。

All of these systems must remain available throughout an event and be supported by emergency generators or battery backup systems. This holistic approach to occupant evacuation is attainable through information sharing between intelligent building systems and advanced models for both threat propagation and people flow.

Conclusion

In conclusion, this paper discussed the use of elevators and stairs as a means to evacuate a tall building in the event of a fire or other threat as permitted by the applicable codes. An objective-based alternative was presented to minimize the risk to occupants. To support this approach, it was shown that building systems could be interconnected, devices repurposed and, under the direction of an evacuation controller, utilized to coordinate the egress of occupants to achieve the desired result. Additionally, a content server could provide information via remote access as a means to allow first responders a "heads up" as to the status of a building before arriving at the command center.

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