Title:	**Elevator Systems and Elevator Evacuation Design**
Authors:	Xiaomei Lee, Gensler Frederick Liu, Gensler Steven Edgett, Edgett Willams Consulting Group Inc. Liming Zhou, Gensler
Subjects:	Building Case Study Vertical Transportation
Publication Date:	2014
Original Publication:	Suzhou Zhongnan Center: In Detail
Paper Type:	1. Book chapter/Part chapter 2. Journal paper 3. **Conference proceeding** 4. Unpublished conference paper 5. Magazine article 6. Unpublished

Elevator Systems and Elevator Evacuation Design
电梯系统及电梯疏散设计

Xiaomei Lee (李晓梅), Frederick Liu (廖世荣) & Liming Zhou (周立明), *Gensler*
Steve Edgett, *Edgett Williams Consulting Group, Inc.*

Because supertall and megatall buildings are a very recent phenomenon, there are no specific building codes written for them. For any building over 50 stories, providing direct elevator service creates a huge and unwieldy core, so alternative systems must be carefully reviewed while ensuring the safety, comfort and convenience of tower occupants. Applicable high-rise codes are used as a guide, with interpretation and modification to suit these objectives. This chapter describes the elevator design, operational system and elevator emergency responses for the Suzhou Zhongnan Center. The design of the vertical transportation system is a collaborative effort between the client (Zhongnan Group), the design team (Gensler and its consultants), associate architect (ECADI), elevator consultant (Edgett William Consulting Group) and several elevator manufacturers.

由于超高层建筑于近代兴起，因此没有专门的建筑规范相对应。对于超过五十层高的大楼，直接电梯服务使用的核心筒大且笨重，因此在确保塔楼住户安全、舒适及便利性的同时，须仔细选择电梯系统。电梯系统应采用适用的高层规范作为设计指引，并进行解释及修订以满足以上目标。 本文对中南中心 (729米) 的电梯设计、操作系统及电梯应急响应进行了说明。垂直交通系统的设计经业主 (苏州中南中心投资建设有限公司) 、设计团队 (Gensler及其顾问公司) 、国内建筑设计单位 (华东建筑设计研究院) 、电梯顾问公司 (Edgett William Consulting Group) 及多个电梯制造商协作完成。

Overview

Safety is the number-one priority in every building design, and vertical transportation plays a vital role in the circulation and operation of any high-rise building. For supertall and megatall buildings, the vertical transportation system provides the only practical means to enter and leave the building. A well-planned and harmonious vertical transportation design enhances building safety, efficiency and human comfort, providing an environmentally friendly and energy-efficient habitat.

Every building is unique and every building has a different program. In addition, elevator design varies by level of service, business type, locality, culture and client objectives. To realize the maximum efficiency of the building core, passenger elevators used in the building are primarily 1,600-kilogram capacity cars, except those 1,350-kilogram elevators used for apartments, to provide the greater shaft space necessary for higher-speed elevators and to save energy. The use of high-speed shuttle elevators for service offices, apartments and the hotel significantly reduces core space, construction costs and energy usage.

Sky lobbies located at shuttle elevator arrival levels provide extraordinary opportunities for amenities, valuable open spaces and city views for the occupants and public. These spaces encourage social interaction and add economic value to the building.

Design Criteria

"Form follows function" is the methodology in architecture design, yet "Elevator design follows program" is equally essential and fundamental. Elevator design standards vary somewhat for different projects around the world, based on location, client objectives, marketing requirements and the investment value of the project. For this project, the following standards were established and are similar to Class A projects of equivalent scale in China and worldwide (see Table 2.5).

概述

安全问题是每个大楼设计中的首要工作，垂直交通在超高层大楼流通及运行中起着举足轻重的作用。对于超高层大楼来说，垂直交通系统提供了出入大楼唯一的可行方法。精心设计与大楼完美匹配的垂直交通设计改善了建筑安全性、效率及人体舒适度，提供了一个环境友好型且节约能源的栖息地。

每座大楼均独一无二且皆设有不同的业态。除此之外，电梯设计也会因服务楼层、商业类型、位置、文化及业主目标的不同各异。为了最大化大楼核心筒效率，除了公寓中使用的载重为1350千克的电梯，中南中心客梯载重主要为1600千克，以提供高速电梯所需的大井道空间并节约能源。此外，服务式办公、公寓及酒店采用高速穿梭电梯大幅度减小核心筒空间、施工成本及能源使用。

穿梭电梯可到达空中大堂，空中大堂为住户及大众提供了与绝佳的配套设施、开敞空间及城市景观相接触的机会。这些空间鼓励人际互动，提高了大楼的经济价值。

设计准则

"形式服从功能"是建筑设计的一种方法，但"电梯设计服从业态"则至关重要。由于

Office (办公): Zone 2 2区	
Population Density: 人数密度	One Person Per 11 Usable Square meters 平均每人11平方米可使用面积 87.5% Attendance 87.5% 出勤率
Tenancy: 租户类型:	Class A Office 甲级办公
Target Interval: 目标间隔时间:	35 Seconds 35秒
Peak Traffic: 交通高峰:	Morning Arrival Peak 清晨到达高峰
Assumed Demand: 假定需求量:	12.0% of Population in Five Minutes 五分钟内运载12.0%的人数
Service Office (公寓式办公): Zone 3 3区	
Population Density: 人数密度	1.75 Persons Per Unit 平均每套房1.75人
Tenancy: 租户类型:	Service Office 公寓式办公
Target Interval: 目标间隔时间:	45 Seconds 45秒
Peak Traffic: 交通高峰:	Morning Arrival Peak 清晨到达高峰
Assumed Demand: 假定需求量:	7.5% of Population in Five Minutes 五分钟运载7.5%的人数
Residential (住宅): Zone 4 – Zone 7 4区—7区	
Population: 人数:	Studio & 1 Bedroom: 1.5 people per unit 不同户型1室: 每套1.5人 2 Bedrooms: 2.5 people per unit 2室: 每套2.5人 3 Bedrooms: 3.5 people per unit 3室: 每套3.5人 4+ Bedrooms: 6 people per unit 4室以上: 每套6人
Tenancy: 租户类型:	Residential 住宅
Target Interval: 目标间隔时间:	45 Seconds 45秒
Peak Traffic: 交通高峰:	Heavy two-way 双向高峰
Assumed Demand: 假定需求量:	12.0% of Population In Five Minutes 五分钟内12.0%的人
Podium – Ballrooms (裙楼—宴会厅): Zone 1 1区	
Population: 人数:	Event dependent 根据活动而定
Target Interval: 目标间隔时间:	40.0 seconds 40.0秒
Peak Traffic: 交通高峰:	Heavy two-way 双向高峰
Podium – KTV (裙楼—KTV): Zone 1 1区	
Population: 人数:	Event dependent 根据活动而定
Target Interval: 目标间隔时间:	60.0 seconds 60.0秒
Peak Traffic: 交通高峰:	Peak exiting 退场高峰
Observation Deck (观光台):	
Population: 人数:	Unknown 未知
Peak Traffic: 交通高峰:	Heavy two-way 双向高峰

Table 2.5. Elevator design criteria standards for the Suzhou Zhongnan Center
表2.5. 苏州中南中心大厦电梯设计标准

Operation

Microcomputer-based control systems are used to perform control functions of elevators, car operation, group supervision and door control. The base control includes operations required to connect, transfer and interrupt power, and to protect motors against overloading. The elevator control is monitored by the Building Management System, and the network will allow the control systems to communicate with each other, and to allow reprogramming with minimum downtime. The elevator system is designed to include different operating states with different provisions:

位置、业主目标、营销要求和项目投资不同，世界各地的项目采用的电梯设计标准可能有所不同。对于本项目而言，以下标准与中国和世界范围内同等规模的甲级项目标准相当 (见表2.5)。

运行系统

采用微电脑控制系统对电梯、轿厢操作、电梯组监控和电梯门实施控制。基本控制包括电源断电、转换和中断操作，以及电机过载保护。电梯控制由楼宇管理系统监控统，并允许各控制系统互相沟通，确保在最短的停机故障时间内重新编程。电梯系统设计包括不同的操作系统和功能:

- 电梯群控系统: 电梯群控通过与各分区监控系统相连的轿厢和层站按钮实现。轿厢在收到轿厢和层站呼唤后自动减速并在相应楼层停靠，停靠按照数字顺序排序，而非按钮顺序。

- Group Automatic Operation: Automatic operation through car and landing buttons in conjunction with the multiple-zone supervisory system. Cars automatically slow down and stop level at floors in response to car and landing calls, with stops made in numerical sequence, irrespective of the order in which buttons are pressed.
- Destination Control: An automatic operation system, controlled by specialized elevator controller, will assign passengers to specific elevators, using operating algorithms. It directs passenger calls for service to keypads located in each elevator lobby. This system will increase overall elevator performance and efficiency. It will increase building security when used in conjunction with proximity cards.
- Simplex Selective Collective: This control will operate elevators from a single riser of landing buttons and from operating devices in the car.
- Tenant Security: An ability to lock-off floors to prevent access is provided. Activation of the system makes that floor inoperative. This feature can be overridden by any car on independent or emergency operation.
- Standby Power: The master elevator controller can be programmed to monitor standby power operation. The system is designed to ensure that life safety and emergency operations accept software upgrades. Signaling to and from emergency power networks will ensure that emergency generators are not overwhelmed by elevator evacuation, and that the elevators operating on standby power are not shut down prior to being landed at the designated floor. The system is designed to automatically record loaded elevators throughout the building and assign priorities to those with the greatest load and travel distance, or to those which can serve to aid emergency personnel in building evacuation. A real-time database is provided in non-volatile memory of individual car loading and status during normal power operation, as a means to establish priorities during a power failure. When there is loss of normal power, non-firefighting elevators will return to designated egress floors in accordance with set priorities.
- Firefighting Emergency: Elevators are equipped with Firefighter's Emergency Operation in accordance with applicable codes and local jurisdiction. Elevators shall return to main floor upon activation of lobby detectors, lobby recall switch, and/or other dedicated emergency signals. Upon lobby arrival, the system is controlled by the fire department.
- Card Reader Access: The card reader can be used to gain access to any and all levels as desired. Car calls to designated secure levels requires prior activation of the coded card to enable activation of floor buttons. This feature can be overridden by approved building management personnel and fire department officials.
- Earthquake Emergency: Upon activation of earthquake signal, elevators shall turn to emergency operation mode for emergency response personnel and/or fire department, for necessary procedures, depending on the scale of emergency.
- Remote Monitoring: This capability provides an integrated control system that continuously monitors all elevator systems. When the system detects a fault, the control system automatically transmits a signal via a built-in modem directly to the elevator service mechanic or local elevator service company office for an immediate response. The system responds to faults including, but not limited to alarm bells, door locks, door safety systems, earthquake detectors, limit switches, low oil, etc. Its modem device uses the same phone line used for the emergency communication device inside the elevator. However, in the event the remote monitoring system is using the line and someone inside the elevator uses the emergency phone, the monitoring system is disconnected and allows the emergency phone to make its required call.

- 目的楼层控制系统: 是一种自动操作系统，由电梯专用控制器控制，采用操作算法将乘客分配到指定的电梯。该系统将乘客呼唤分配到各个电梯间的按钮上。该系统提高了电梯的总体性能和效率，如与感应卡同时使用，还可强化大楼安保。
- 简单集选系统: 该控制系统采用层站按钮和轿厢内的操作装置实施控制。
- 租户安保系统: 闭锁楼层以防止进出。启动该系统，可使相应楼层无法运行。可通过轿厢或应急操作覆写。
- 备用电源: 总电梯控制系统可编程，对备用电源操作实施监控。该系统的设计确保生命安全和应急操作系统的软件可以更新。应急电源网络发出和接受的信号可确保应急发电机不会因为电梯疏散时而超负荷，同时可确保电梯可利用备用电源运行，不至于在指定楼层停靠之前停止运行。系统设计可自动记录大楼内各处的载客电梯，并能够优先安排载重最大、运行距离最长的电梯，或者在大楼疏散时用于运送救援人员的电梯。实时数据库针对单个轿厢载重以及正常供电运行状态设计了非易失性内存，以便在断电时确立优先顺序。在正常电源断电后，非消防电梯将按照设定的优先次序返回指定的逃生楼层。
- 消防应急: 按照适用规范和地方当局设计的具备消防员应急操作的电梯。激活电梯间探测器、召回开关及/或其它专用应急信号后，电梯将返回主楼层。到达电梯大堂后，系统由消防部门控制。
- 读卡器访问: 采用读卡器进入任何及所有目标楼层。如需通过轿厢呼唤到达租户安保系统的指定楼层，需要通过代码卡激活楼层按钮。但经批准的管理人员和消防官员可以无视这一功能。
- 地震应急模式: 在激活地震信号后，电梯将返回应急工作人员及/或消防部门应急操作模式，以便按照应急规模的大小进行必要的操作。

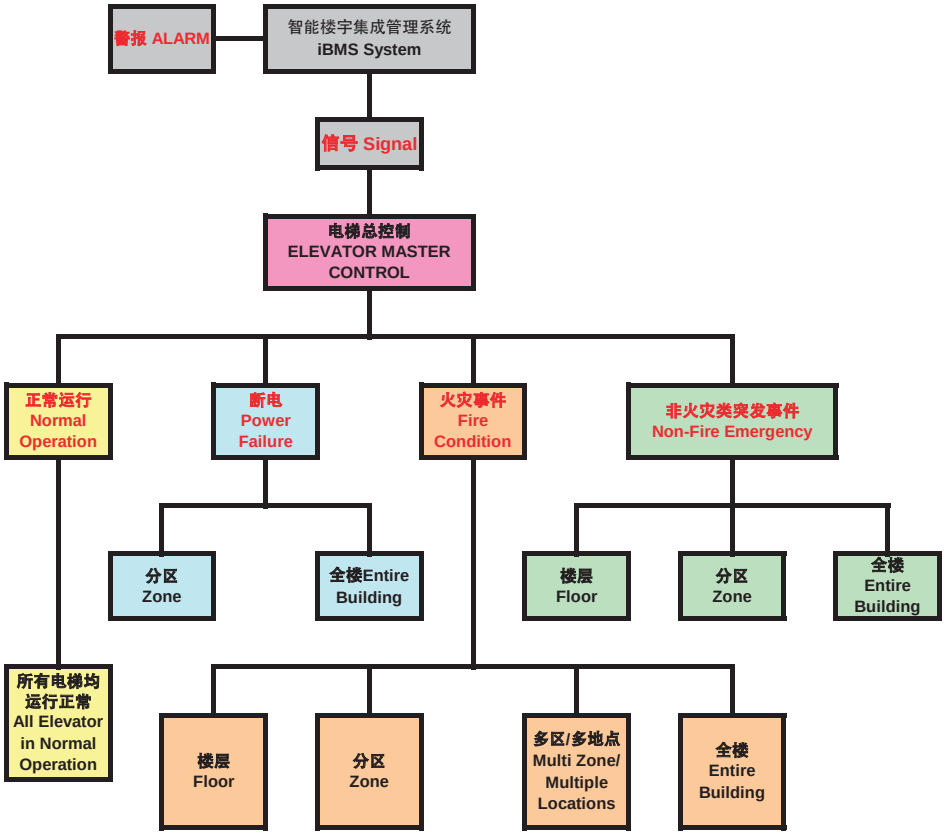

Figure 2.17. Suzhou Zhongnan Center Elevator Operation Scenarios (Source: Gensler)
图2.17. 苏州中南中心电梯运行流程 (来源: Gensler)

Energy-Saving Measures

Maintenance and operating costs are some of the key factors in project success. Elevators for this project are based on the latest and most energy-efficient elevator designs internationally. Several energy-saving measures are incorporated into the elevator design.

Permanent magnet AC motors, energized by Variable Frequency and Variable Voltage AC drives, dramatically reduce energy consumption and maintenance.

- Motors are fully regenerative, producing power under hauling load conditions in both upward and downward travel.
- Destination control for service offices.
- Elevator control systems will reduce energy usage during non-peak periods, based on demand to optimize energy usage and extend equipment life.

Elevator Evacuation

As time goes on, technology evolves; demands change; buildings get taller; people evacuation becomes more and more challenging. All of these factors mean the actions required to protect human life become more and more intricate. However, the basic philosophy of protecting building occupants remains the same. For a building of this height, the use of elevators for emergency evacuation becomes an integrated part of the overall building design and building egress system.

Due to the extraordinary height of this building, different operation scenarios (see Figure 2.17) were considered, including the normal operation condition, the building power outage conditions (see Figure 2.18), the fire emergency conditions (see Figure 2.19) and the non-fire building evacuation condition (see Figure 2.20).

A programmable master elevator controller is used to perform different modes of standby power operation. When in standby power mode, passenger and service elevator acceleration, deceleration and speed can be modified to maximize the efficiency of standby power, while all

- 远程监控: 提供不间断监控所有电梯系统的综合控制系统。当系统发现故障时，控制系统能够自动通过内置解调器将信号传输到电梯服务技工或当地电梯服务办公室，供其立即采取行动。系统可以响应的故障包括但不限于: 报警、锁门、门安全系统、地震探测器、限位开关、油位低等。解调器与电梯内的应急通讯设备使用同一条电话线。但如远程监控系统使用该线路，而电梯内的人使用应急电话，监控系统将断开，方便通过应急电话进行呼叫。

节能措施

维护和运行成本是项目成功与否的关键因素。该项目的电梯基于最新、最节能的国际电梯设计方案。电梯设计采用了数个节能方法。

变频及变压交流驱动的永磁交流电机大幅降低能源消耗和维护操作。

- 电机完全采用可再生设计，在电梯在荷载上行和下行时都可产生电源。
- 公寓式办公的目的楼层控制系统
- 电梯控制系统将在非高峰期间根据需求降低能源消耗，以便优化能源利用率，延长设备寿命。

电梯疏散

随着时间的推移、技术的进步以及需求的变化，建筑物越来越高; 人员疏散面临越来越多的挑战; 保护人生命安全的措施也越来越复杂。但是，保护建筑物用户安全的基本理念是始终不变的。对于这种高度的建

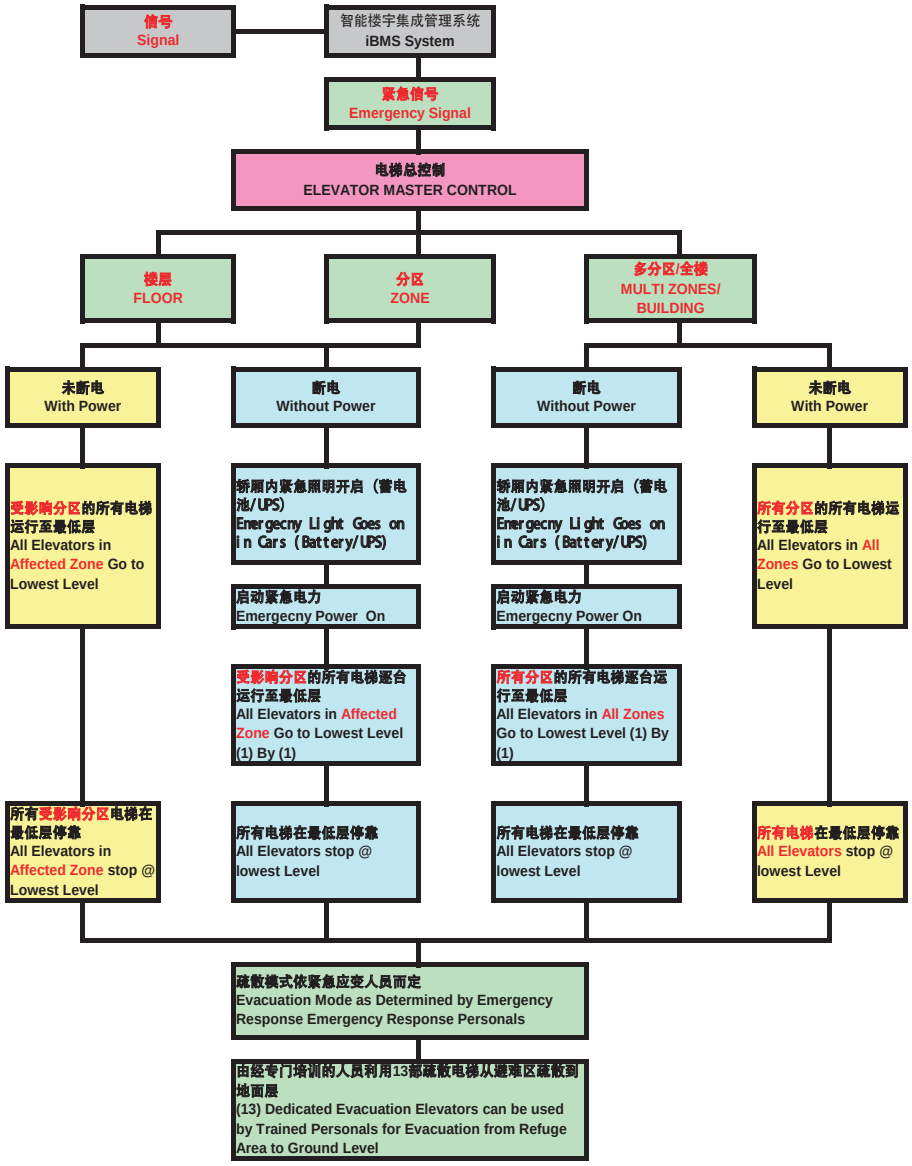

Figure 2.18. Suzhou Zhongnan Center Elevator Operation – Power Failure Condition (Source: Gensler)
图2.18. 苏州中南中心电梯运行——电力故障情况 (来源: Gensler)

firefighting lifts and evacuation lifts are programmed to operate at standard speed and duty. The evacuation system is effected through software to ensure that life safety and emergency operation can be optimized throughout the life of the building. The Building Management System is designed to coordinate signaling from emergency power networks to ensure that emergency generators are not overwhelmed by various modes of elevator evacuation. The system is designed to automatically provide inventory information of loaded elevators throughout the building and assign priorities to those with the greatest load and travel distance, or those which can serve to aid emergency personnel in building evacuation. It provides a real-time database in non-volatile memory of individual car loading and status (i.e.: existing demands for operation of the elevator) during normal power operation, as a means to establish priorities during a power failure.

Building Power Outage

In the event of a loss of normal building power, the system will identify the power available from the emergency generator network and allocate the use by priority as follows; firefighting elevators first, then dedicated shuttle elevators, then passenger elevators, and then non-fire freight and service elevators.

The primary objective is to first bring elevators throughout the building to a point where passengers are off-loaded at the nearest level during power outage. Once this automatic operation has completed, building operation personnel will be able to manually select

筑，利用电梯进行紧急疏散成为了总体建筑整体设计及建筑疏散系统的必不可少的一部分。

由于建筑物的超凡高度，需考虑不同的运行模式 (见图2.17)，包括正常运行情况、建筑供电中断情况 (见图2.18) 、火灾紧急情况 (见图2.19) 及非火灾建筑疏散情况 (见图2.20) 。

利用可编程的主电梯控制器进行备用电源的多种模式操作。在备用电源模式下，可调整客梯及服务电梯的加速、减速及速度，以最大化备用电源效率，同时对所有消防电梯及疏散电梯进行编程，以确保在标准速度及功率下运行。通过软件 疏散系统，以确保建筑内人群的生命安全最大化及紧急操作。建筑管理系统的设计旨在协调应急电源网络发出的信号，以确保应急发电机在多种电梯疏散模式下不过载并能够正常运行。系统的设计旨在自动提供建筑内乘载电梯的信息，同时优先分配负荷

elevators, based on available power confirmation of safe operation, to provide a minimal level of elevator service through the duration of the power outage.

Fire Condition

Fire emergency operation and procedure shall be executed in accordance with all building codes and local fire department approval.

最大、运行距离最长的电梯或那些为建筑疏散中用于紧急救援人员服务的电梯。在正常电力操作过程中，系统在非易失性存储器中提供每个轿厢装载及状态的实时数据库 (如: 电梯操作的现状需求)，作为在电力中断情况下确定优先顺序的一种方法。

建筑供电中断情况

在正常建筑供电中断的情况下，系统将确定应急发电机网络的可用电力，并按照以下顺序分配电力: 首先为消防电梯，其次为专用穿梭电梯，之后依次为客梯、非火灾货梯及服务电梯。

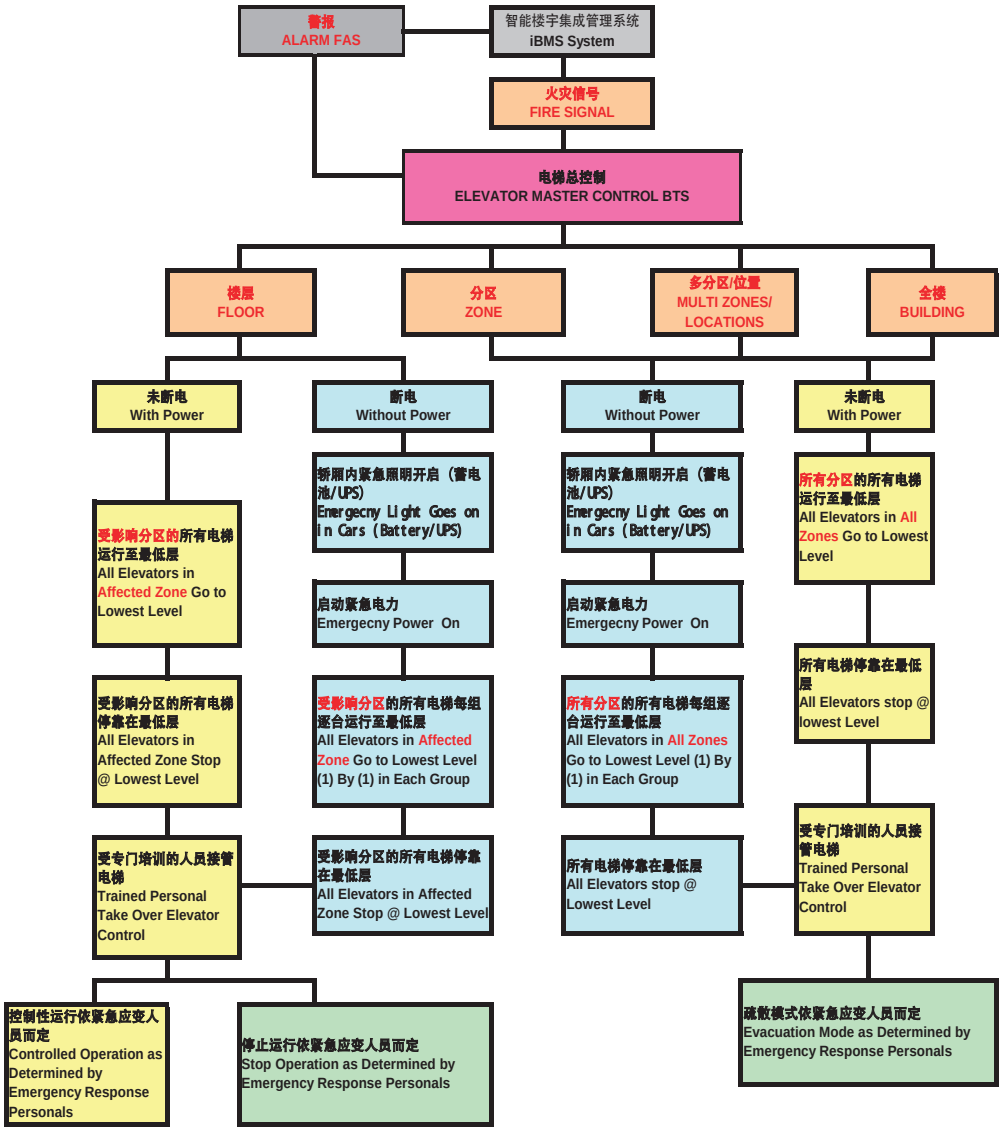

Figure 2.19. Suzhou Zhongnan Center Elevator Operation – Fire Condition (Source: Gensler)
图2.19. 苏州中南中心电梯运行——火灾情况 (来源: Gensler)

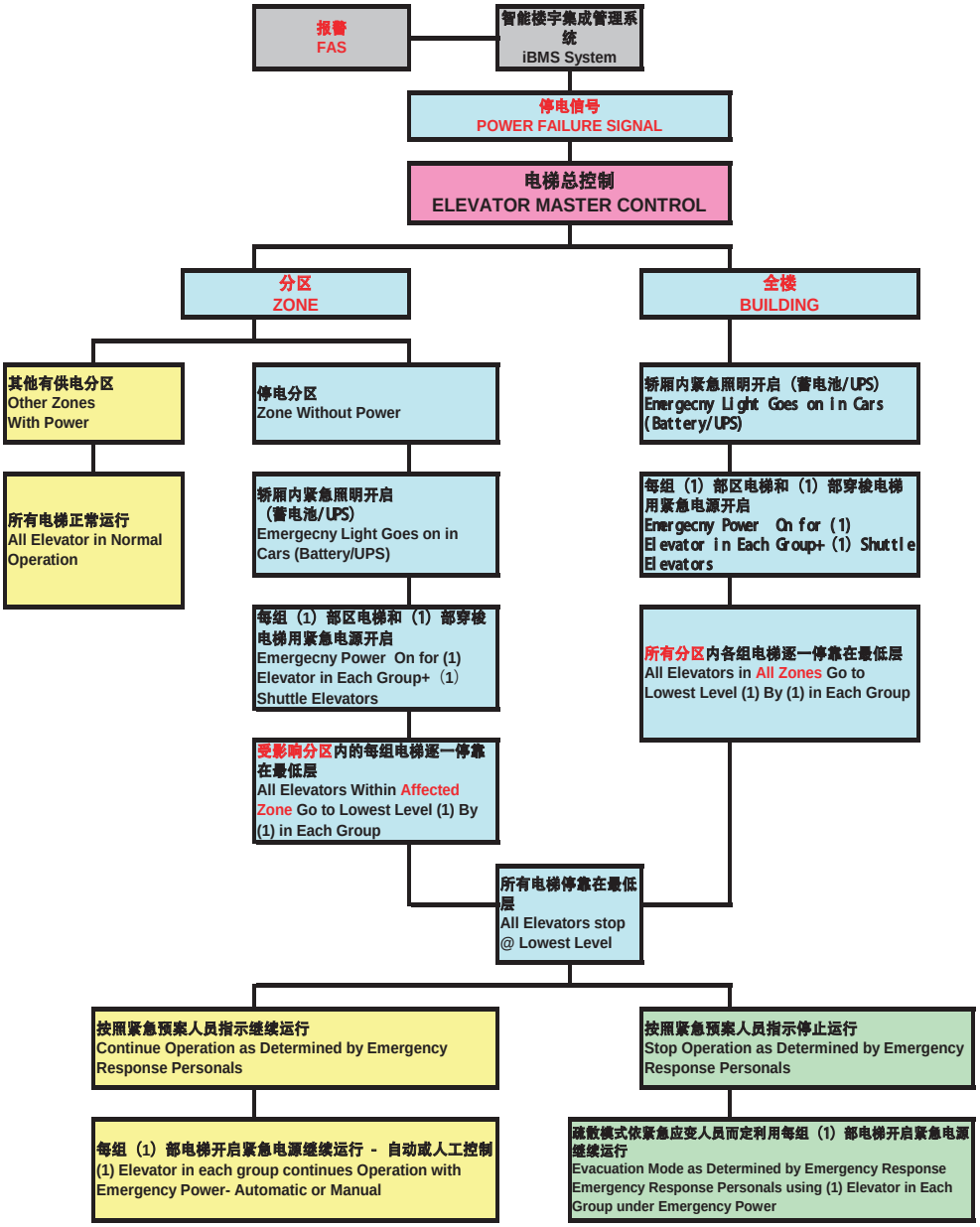

Figure 2.20. Suzhou Zhongnan Center Elevator Operation – Non-Fire Emergency (Source: Gensler)
图2.20. 苏州中南中心电梯运行——非火灾紧急情况 (来源: Gensler)

During the fire condition, elevators will first return to the main floor via activation of lobby detectors and/or lobby recall switch. In the event of a power interruption before, during or after a fire emergency, the system will identify the power available from the emergency generator network, prioritize orderly evacuation of elevators serving that portion of the building prior to general elevator evacuation; evacuating passenger elevators first, then fire/service elevators, and then non-fire freight and service elevators.

In this mode, occupants are normally advised to evacuate to dedicated refuge areas in mechanical levels and proceed based on building emergency response team directions. Several dedicated shuttle elevators can be used by trained emergency

主要目标是在电力中断时，将建筑内的电梯集中到某个点，使乘客可以在最近楼层下客。一旦完成这项自动操作，建筑操作人员将能够基于安全操作的电力确认手动地选择电梯，在电力中断的情况下提供最少的电梯服务。

火灾情况

火灾紧急情况下的操作及流程应按照建筑规范及当地消防部门的批准进行。

在火灾情况下，电梯首先通过大堂探测器和/或大堂召回开关返回主楼层。在火灾情况发生之前、过程中或发生之后出现的电力中断情况下，系统将确定应急发电机网络的可用电力，在进行普通电梯疏散前，按顺序安排服务该部分的电梯的疏散工作: 首先疏散客梯、其次为消防/服务电梯，然后为非火灾货梯及服务电梯。

在该模式下，通常建议住户疏散至机械层的专用避难区域，并按照建筑紧急应变小组的指令进行疏散。经过培训的应急响应人员可利用一些专用的穿梭电梯协助疏散工作，这些电梯还可用于将紧急救援人员输送至建筑首层或建筑内的某一特定区域。

非火灾紧急情况

随着社会越来越复杂，随时随地都可能发生各种突发事件; 建筑设计也越来越复杂多变。安全的建筑疏散要求合理的规划与准备。在不同紧急情况类型及范围的基础上，要求进行整个建筑或部分区域的疏散。在非火灾疏散情况下，经过训练的应急响应人员将决定疏散流程及要求的疏散范围。在火灾情况发生之前、过程中或发生之后出现的电力

response personnel to assist evacuation and can also be used for transportation of emergency personnel to ground level or to a specific zone of the building.

Non-Fire Emergency

As our society becomes more and more complex, unexpected situations could happen anywhere, any time any place; building design becomes more and more intricate as a result. Safe building evacuation requires proper planning and preparation. Based on the type and extent of an emergency condition, partial or total building evacuation may be required. During non-fire evacuation condition, trained building emergency response personnel will determine the procedure and will determine extent of evacuation required. In the event of a power interruption before, during or after a building emergency, the system will identify the power available from the emergency generator network and apportion the power as outlined in the emergency operation program. Where the emergency is limited to one or two zones, the system prioritizes orderly evacuation of elevators serving that portion of the building prior to general elevator evacuation; passenger elevators are evacuated first, then non-fire freight and service elevators.

In this mode, shuttle elevators can be used to assist evacuation and for firefigther use at refuge levels, similar to the Fire Condition above.

The control of elevators is normally automatic, based upon real-time monitoring of available generator power, and will then allow manual control of elevators, up to the limit of generator capacity. Measures will include automatic reduction of elevator energy consumption in order to provide the greatest number of operating elevators during emergency power operation. All elevators used for evacuation shall be designed in accordance with applicable codes similar to firefighter lifts.

Proficient elevator design is essential. Yet, safe evacuation requires a well developed program, which consists of clearly defined/written guidelines, step-by-step procedures, dedicated personnel and the regular training and collaboration of governing agencies. The building owner should initiate the development the program with the design team and fire department at an early design stage, so as to incorporate all necessary requirements.

Conclusion

While efficient day-to-day transportation of building occupants is the primary objective of the elevator system, the design of the system must consider occupant safety as the number-one priority in every multi-floor building design. A megatall building such as the Suzhou Zhongnan Center creates an enormous challenge for the design team as the need for space, structure, transportation and occupant safety are carefully balanced in the design and layout of the building. Similarly, emergency operating conditions for such a building must be considered as a fundamental component in their design, with consideration given to conditions which affect the building occupants. Finally, any high-rise building will need to consider occupant evacuation in various emergency modes as a basic requirement of the design of the building and its internal systems. Each such building constitutes a vertical city and must be treated accordingly.

中断情况下，系统将确定应急发电机网络的可用电力，并按照应急操作方案进行分配。如果紧急事件仅限于某一特定区域或两个区域，在进行普通电梯疏散前，按顺序安排服务于该部分的电梯的疏散: 首先疏散客梯、其次为非火灾货梯及服务电梯。

在该模式下，可利用穿梭电梯协助疏散，并作为避难层的消防电梯，这一模式与以上火灾情况下的模式类似。

电梯控制通常基于发电机的实时监控，还可对电梯进行手动控制，以发电机容量为上限。相关措施将包括电梯能耗的自动减少，以确保紧急电源操作过程中能够提供最多的电梯同时运行。所有用于疏散的电梯应按照适用规范要求进行设计，与消防电梯设计类似。

专业的电梯设计最为关键。然而，安全疏散还要求充分的规划，包括明确规定的指导/书面指南、逐步流程、专人负责、定期培训及主管机构的配合。建筑业主应在设计初期与设计团队及消防部门合作，共同编制方案，以整合所有必要要求。

总结

电梯系统的首要目标为保证建筑物用户有高效的日常垂直交通，系统设计必须将用户安全作为每层建筑设计的第一要务。像苏州中南中心这类的超高层建筑为设计团队带来了极大挑战，因为在建筑设计及建筑布局中必须保持空间、结构、交通及用户安全的精确平衡。同样地，此类建筑要求的应急运行条件必须作为设计的基本元素，同时还应考虑影响建筑用户的各种条件。最后，任何超高层建筑都应将多种紧急模式下的用户疏散作为建筑及内部系统设计的基本要求。每栋超高层建筑都构成了一座立体城市，因而都应得到相应处理。

References (参考书目):

Vertical Transportation Schematic Design Report (Source: Edgett Williams Consulting Group)