

# 全自动运行线路清客和疏散场景分析\*

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**摘要** 全自动运行线路运营中, 清客和疏散是保证乘客安全的重要运营场景。介绍了清客和疏散的含义, 采用事件流程分析法全面分析了各种情况下的清客和疏散事件流程, 并总结出了通用的清客和疏散场景的运行流程。

**关键词** 城市轨道交通; 全自动运行; 清客; 疏散; 场景分析  
**中图分类号** U231+.6; U293.1+3

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## Analysis of Passenger Detrainment and Evacuation Scenarios on FAO Line

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**Abstract** In the operation scenarios of FAO (fully automatic operation) lines, passenger detrainment and evacuation are two important operational scenarios to ensure the safety of passengers. The meanings of passenger detrainment and evacuation are introduced. By carrying out event flow analysis on passenger detrainment and evacuation scenarios, the event process under various circumstances are analyzed comprehensively, and the general passenger detrainment and evacuation scenario operating procedure is summarized.

**Key words** urban rail transit; FAO (fully automatic operation); passenger detrainment; evacuation; scenario analysis

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清客是一种在站台区域让车上乘客下车, 并禁止站台乘客上车的运营行为。全自动运行线路的清客一般发生在终点站、折返站等固定站台, 以及有临时需要清客的站台。

疏散是当正常上、下车条件不完全具备的情况下, 需要车上乘客离开列车进入线路、维修区域或应急区域的应急运营行为。全自动运行线路的疏散一般发生在区间、列车未全部进入或离开站台区

域的情况下。

清客和疏散功能可以保证全自动运行线路正常和异常情况运营时乘客能够安全地下车。

根据国际电工协会标准 IEC 62290-1, 列车运行自动化等级分为 GoA0、GoA1、GoA2、GoA3、GoA4 共 5 级<sup>[1]</sup>。其中满足 GoA3 和 GoA4 要求的统称为全自动运行系统。本文将着重对 GoA3 全自动运行线路的清客和疏散场景进行分析。

## 1 清客

### 1.1 基本流程

1) 信号系统监控列车在折返站和终到站(含临时清客站台)停车并判定停稳且停准。

2) ATS(列车自动监控)子系统通过 ATO(列车自动运行)子系统向车辆网络发送清客工况指令, 并通过硬线向车辆发送列车开门使能并撤销保持列车门关闭信号, 以控制列车车门打开; 同时向站台门系统发送开门命令, 控制站台门打开。

3) 车辆网络接收到清客工况指令后, 自动触发车载广播和 PIS(乘客信息系统), 提醒乘客下车, 同时联动车载 PIS 提示乘客下车。

4) 信号系统的 ATS 联动车站广播, 提醒站台乘客不能上车; 同时联动站台 PIS 提示本站清客, 乘客请勿上车。

5) 在收到人工清客完成确认信号后, 信号系统的 ATO 子系统命令关闭车门和站台门, 清客结束。

整个过程中, 控制中心调度人员可调取站台和车载 CCTV(闭路电视)画面观察清客情况。整个清客业务的基本功能流程如图 1 所示。

### 1.2 触发清客场景

正常情况下, 对固定站台的清客被视为计划内清客。它由信号系统的 ATS 子系统根据列车计划

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自动触发。

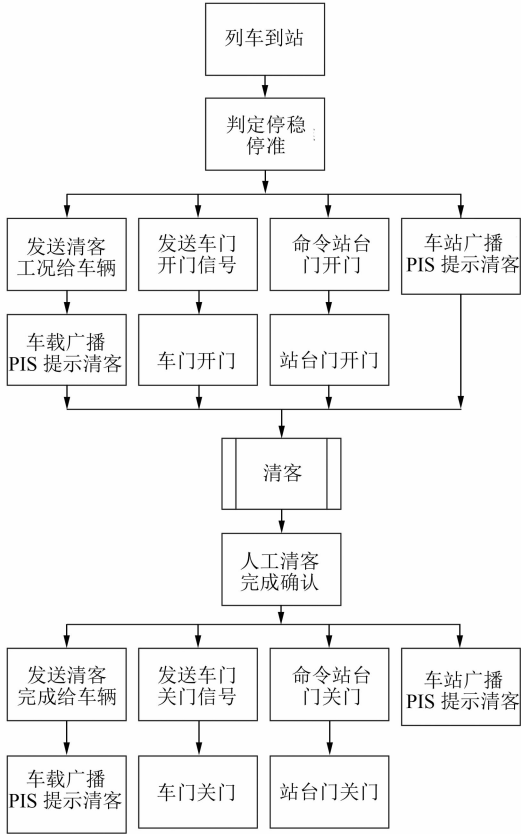


图 1 清客功能基本事件流程

Fig. 1 Basic event flow of passenger detrainment function

而对临时清客业务,中央调度人员(行调或乘客调)通过乘客调度系统或者直接通过信号系统的ATS子系统下达清客命令。或者将要进行临时清客的列车扣在站台,直至清客完成确认。

清客场景触发流程见图 2。无论哪种情况下的清客,均要求列车在站台范围内停稳、停准,且保持

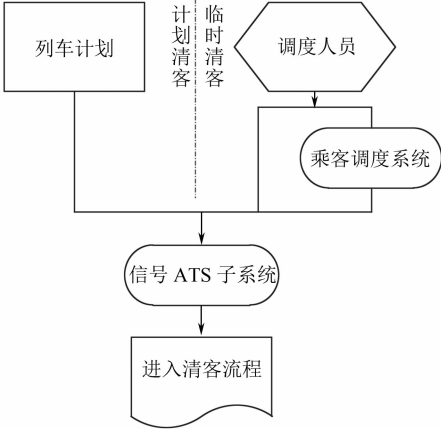


图 2 清客场景触发流程

Fig. 2 Triggering process of passenger detrainment

车门和站台门打开状态。车门和站台门的关闭须收到清客确认完成的信号或人工指示才被允许。

1.3 清客完成确认

对于固定站台的清客业务,通常会在站台设置“清客确认”按钮。该按钮通过硬线接入信号系统的联锁或者轨旁 ATP(列车自动防护)子系统。正常情况下,站台工作人员会查看该站台列车的清客情况,在确认车内无人、站台门和车门之间无障碍、站台上无人靠近站台门等条件后,再按压“清客确认”按钮。信号系统收到该信号后,触发各系统清客完成确认流程(见图 3)。

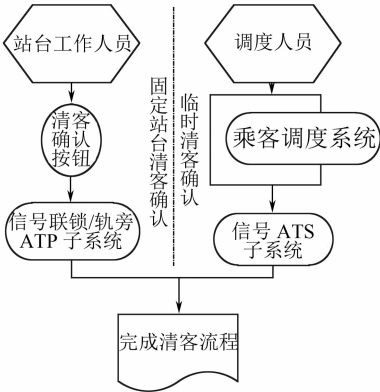


图 3 清客完成确认流程

Fig. 3 Confirmation process of passenger detrainment completion

而可能执行临时清客业务的站台,一般不会设置“清客确认”按钮。需要中央调度人员(行调或客调)通过车辆和站台 CCTV 画面实时查看清客状况,进行远程监控和确认。在这种情况下,也可以要求多职能队员或者车站值班人员到站台进行辅助监督,并通过无线调度系统进行人工确认。如果条件允许,可以利用智能视频图像识别等先进技术,通过车辆和站台 CCTV 图像,快速准确地自动生成清客确认辅助信号,从而自动进行清客确认。

在确认清客完成后,通过乘客调度系统或者直接通过信号系统的ATS子系统下达“清客确认”软命令,触发各系统清客完成流程(如图 3 所示)。

2 疏散

当全自动无人驾驶列车在区间运行时发生设备故障等情况,但线路条件、车辆状况等可以支持维持列车运行至前方站台,列车将开行至前方站台停车。如列车进站后对位停准,则执行清客流程,必要时进行站台疏散;如列车对位不准,在站台区

域迫停需要执行到站疏散流程。

当全自动运行列车在区间运行时因设备故障或其他突发事件迫停;短时间无法恢复运营,则需要工作人员至现场进行指挥,按运营要求和相应的应急预案执行区间有序疏散流程。当列车迫停区间时,未有工作人员到达现场,乘客自行打开车门进入区间线路,则需要中央调度人员远程引导乘客在区间进行疏散。

另外,考虑到最不利情况,当全自动运行线路发生火灾、爆炸和车地通信中断等危及乘客安全的紧急状况,导致列车不得不在区间迫停时,乘客须自行打开车门或逃生门进行逃生。在此情况下,需要中央调度人员远程引导乘客在区间进行疏散。引发疏散的各种事件及相应的疏散预案如表 1 所示。

表 1 引发疏散的事件及对应预案表  
Tab.1 Events inducing evacuation and corresponding plans

引发疏散的事件	疏散预案
设备故障或车厢内/外部火灾,但列车能维持运行至下一站且对标停准	清客+站台疏散
设备故障或车厢内/外部火灾,但列车能维持运行至下一站,未对标停准	到站疏散
列车火灾、供电故障、轨旁设备故障,导致列车迫停区间,乘客未打开车门	区间有序疏散
列车火灾、供电故障、轨旁设备故障,导致列车迫停区间,乘客自行打开车门进入区间线路	远程引导区间疏散
区间火灾、爆炸、车地通信中断等危及乘客安全事件,导致列车迫停区间	远程引导区间疏散
正线列车事故(挤岔、脱轨、脱钩、冲突、倾覆),需要疏散乘客	区间有序疏散

2.1 到站疏散基本流程

- 1) 中央调度人员通过信号系统的 ATS 子系统发现进站列车未停准,且触发紧急制动不能动车。
- 2) 中央调度人员调取相关的 CCTV 画面查看,并安排车站工作人员或多职能队员打开应急门。
- 3) 中央调度人员(行调或客调)通过车载广播指导乘客打开应急门所对应的车门,或者安排多职能队员打开应急门和列车乘务门(全自动运行列车不设置专用乘务门,而是将靠近站台一侧运行方向最前端的第 1 个门作为乘务门)进入列车协助乘客打开车门。如列车乘务门和应急门未对准,则须从端头门外侧小站台隔离栏处打开隔离栏活动门,再打开乘务门进入列车。
- 4) 车站工作人员在站台应急处置室内广播告知乘客客流引导信息,并进入车厢进行疏散。

列车到站疏散流程的事件流如图 4 所示。

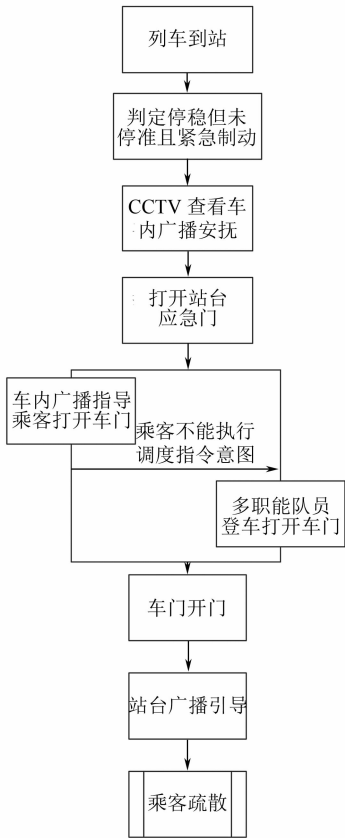


图 4 到站疏散流程的基本事件流  
Fig. 4 Basic event flow of passenger detrainment upon train arrival

2.2 区间有序疏散的基本事件流程

- 1) 中央调度人员通过信号系统的 ATS 子系统封锁事发区间,安排相关车站工作人员通过车控室或应急处置室 ATS 子系统设备确认故障位置后,至现场组织区间疏散。
- 2) 中央调度人员(客调或行调)通过车载广播及车载 PIS 做好车内乘客安抚工作,并通过车载 CCTV 查看情况。
- 3) 中央调度人员确定疏散方向,根据确定的疏散方向和疏散预案启动相应的区间通风模式及区间疏散标识,打开区间照明。
- 4) 多职能队员到达迫停列车,进入车内打开列车逃生门开始区间疏散,原则上引导乘客至车站疏散。
- 5) 中央调度人员配合现场进行区间疏散车厢广播及设置区间疏散车载 PIS 显示。
- 6) 车站工作人员在车控室或应急处置室向车站乘客广播车站应急客流组织情况,并接应疏散乘

客从站台端头门引导至站台。

7) 区间疏散完毕后,中央调度人员(行调和客调)与现场负责人及车站值班员确认人员出清、设备恢复、具备运营条件,然后取消区间封锁,恢复正常运行。

区间有序疏散的基本事件流程如图 5 所示。

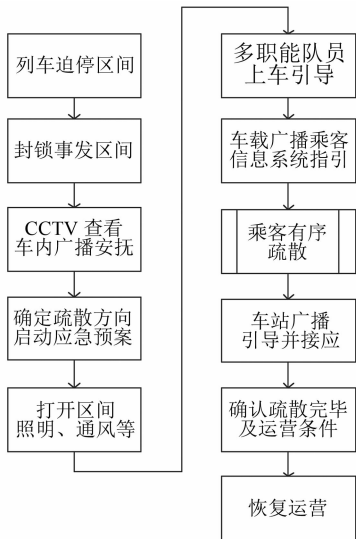


图 5 区间有序疏散的基本事件流程

Fig. 5 Basic event flow of interval orderly evacuation

### 2.3 远程引导区间疏散基本事件流程

如图 6 所示,远程引导区间疏散的基本事件流程如下:

- 1) 中央调度人员根据信号系统的 ATS 子系统报警信息、车辆调度和乘客调度系统报警信息,获知列车须迫停区间。
- 2) 中央调度人员对前后相邻列车实施扣车或截停后续进入区间的列车,封锁事发区间。
- 3) 中央调度人员安排多职能队员触发工作人员防护开关,进入区间登乘迫停列车。
- 4) 中央调度人员根据报警信息和车载 CCTV 视频,获知列车车门或逃生门已被乘客解锁,中央调度人员打开区间照明。
- 5) 中央调度人员通过车载广播指挥乘客打开车门或逃生门,引导乘客疏散至相关车站。
- 6) 中央调度人员安排相关车站工作人员至现场接应。
- 7) 车站工作人员通过车控室/应急处置室确定区间疏散位置后,赶赴现场接应疏散乘客从站台端头门引导至站台。
- 8) 区间疏散完毕后,中央调度人员与现场负责

人及车站值班员确认人员出清、设备恢复、具备运营条件后,取消区间封锁,车站值班员恢复 SPKS (人员防护开关),恢复正常运行。



图 6 远程引导区间疏散基本事件流程

Fig. 6 Basic event flow of interval evacuation with remote guidance

远程引导区间疏散时,多职能队员赶往事发列车与乘客下车自行疏散同步进行;多职能队员赶往事发地点后,主要工作是清障、恢复设备和确认列车运营条件。该情况下,一般需要引导乘客向远离事发地点的一侧车站疏散撤离。仅当确认区间内没有致命气体和尘埃等扩散物时,才应根据其他条件或预案引导乘客向两端疏散。

### 2.4 疏散场景的注意事项

由于疏散是在乘客正常上、下车条件不完全具备的情况下,乘客可以离开无人驾驶列车的一种场景。为保证乘客安全,疏散流程和规则的制定需要格外注意一些不利因素,并给出相应对策。

在疏散过程中,只有当列车停稳后,车门才能被允许打开,且参与疏散的人员(除乘客外)和信号系统共同保证只有“安全侧”的车门被打开。如果乘客因车门在站台区域外打开能够进入轨道,运营人员应该能有效监控乘客动向,并在列车周边建立防护区域以防止其他列车驶入。

对采用第三轨供电的线路,应在供电轨周围设置警示标识。列车车门打开前应确保断电,且尽可能在远离供电轨的一侧进行疏散,并通过远程广播进行持续语音引导,如条件允许还应通过远程视频进行实时监控,以有效防止乘客疏散过程中触电。

如果车站或区间疏散是由火灾、爆炸、毒气泄漏引起的,还应确保乘客疏散撤离方向与通风方向一致,并能够进行有效的远程或现场引导。

另外,远程引导区间疏散时,要求调度人员及时、准确地判定事发地点、可疏散方向和列车迫停位置,并及时远程告知乘客疏散方向,以最大程度地提高疏散效率、降低疏散风险。

### 3 结语

新一代的全自动运行列车控制系统以列车运行全自动化为目标,同时兼顾运维智能化,已经得到了社会的广泛认同,且正处在广泛应用的技术发展阶段。

全自动运行运营体系的运营场景复杂,专业结合程度高,人机协作要求更加默契。对清客、疏散场景进行研究并建立有效的应急机制和预案,除能保证乘客正常上、下车之外,也能够保证乘客安全到达目的地,突发情况下乘客亦能安全下车并到达指定地点。这对提升以乘客为本的运营服务质量有深远意义。

另外,全自动运行运营体系中“多职能队员”将

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标识出数据的来源位置。在任何时间,显示器将至少显示 2 个遥感站的数据。

相比传统无人驾驶地铁中的基本功能,如休眠、唤醒、远程复位等外,香港机场 APM 信号系统还支持列车灵活编组运营,远程选择 VATC,以及适配机场不同区旅客(陆侧和空侧)的极复杂门控逻辑等。

### 3 结语

从香港机场 APM 信号系统可以看出,相比传统的地铁信号系统,其与外部专业更多的接口使得 APM 信号系统与外部专业的连接更加紧密,而灵活的功能配置可以满足更多样化的客户需求,在大量新建及改造机场项目的助推下,匹配 APM 的信号系统将大有可为。

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起到比“司机+维护人员+巡视人员”更大的作用,也必须具备更高的多专业综合知识、多任务处置水平、应急处置能力等综合业务素养。

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(Continued from Commentary)

city to have held both Summer and Winter Olympic Games in the world, and the first capital city to hold Winter Olympics in the world. However, Beijing is over 170 km away from Zhangjiakou Competition Zone, and over 70 km away from Yanqing Competition Zone, which arises attention towards solutions to transportation problem.

Beijing Winter Olympics has fabricated a green public transport network with rail transit as backbone. Visitors can arrive at each arena easily by public transport means such as metro, high-speed railway and bus. To construct an efficient rail transit system with fusion of 4-network, high-speed railway, intercity railway, suburban railway and urban rail transit, it is necessary to carry out planning and design under the ideology guidance of system integration, intelligentization and smartness, green low-carbonization, and to formulate integrated planning between management system and transportation organization, across cities, provinces and multiple transport means.

From the Beijing-Zhangjiakou Railway designed and completed by Zhan Tianyou in 1909, to the Beijing-Zhangjiakou High-speed Railway launched in 2019, China Railway has walked 110 years to this historical moment encountering Winter Olympics. On 30 December 2019, Fuxing Smart EMU departed from Qinghe Railway Station of Beijing North Railway Station, traveling over 100 m deep below the Great Wall of Badaling, arriving at Zhangjiakou of Hebei province, taking only 48 min.

On 1 December 2021, Beijing-Zhangjiakou High-speed Railway Yanqing Branch Line was successfully launched. It takes only 26 min from Qinghe Railway Station to Yanqing Station. Qinghe Railway Station, Yanqing Station are integrated hubs coordinating multiple transport means including high-speed railway, suburban railway, metro, bus, taxi. Shuttle bus at Yanqing Station has direct routes to every arena in Yanqing Competition Zone within 30 min. 11 routes of cable transport inside Yanqing Competition Zone provides mountain transport network for athletes and audience. It takes only 30 min from Yanqing Winter Olympic Village at the foot of Small Haituo Mountain to reach the Xiaohaituo Alpine Skiing Field located at an altitude of 2 198 m. With Beijing Metro Line 11 starting operation by the end of this year, the six stadiums in Beijing Competition Zone (Capital Indoor Stadium, National Speed Skating Oval, National Indoor Stadium, Wukesong Arena, National Aquatics Center, Big Air Shougang) will have all entered the metro coverage. Beijing-Zhangjiakou-Yanqing rail transit network is technically supported by modern high technologies:

**Smart Passenger Service.** The system adopts AFC gate that integrates human face recognition, temperature detection, health code scanning for entry service. The intelligent equipment set in station area, such as open passenger service center, service robot, inquiry machine, will provide connection navigation service among rail transit, Winter Olympics and cities. During Winter Olympics, consumers can choose digital yuan online or hardware wallet according to their own habits and preferences, enjoying using e-RMB in 7 major life scenes including transportation, food and accommodation, shopping, sight-seeing, medical support, telecommunication, entertainment. Riding the wave of Winter Olympics, rail transit departments will launch CN-EN automatic ticket vending machine and CN-EN ticket APP. The current version of railway 12306 APP is already embedded with multi-language functionality, ready for online demonstration and utilization. The delight Beijing Winter Olympics brings about might surprise visitors beyond expectation.

**Intelligent Construction Field.** During the construction of the system, through digitalized technical practice at each production link, with BIM technology application as core, a BIM-based design parametric collaborative platform is constructed. Auto-collection and information interoperation of construction data is achieved on the engineering construction management platform based on BIM+GIS. It supports collaborative management, decision-making assistance and trackable closed-loop management of construction quality among all parties involved. In the project of New Badaling Tunnel and Badaling Great Wall Railway Station, layered underground excavation cave group is innovatively adopted for station design and construction. The intelligent construction of Qinghuayuan Tunnel adopts full-prefabrication shield tunnel. Guanting Reservoir Bridge is constructed using factory construction technology system of steel truss girder modularization, automation and intelligentization.

**Intelligent Equipment Field.** High-speed EMU automatic operation at the speed of 350 km/h is accomplished first time worldwide. With more than 2 700 sensor monitoring points set on the whole vehicle, real-time detection of high-speed train and operation environment condition is realized. Through data mining, PHM (prognostic and health management) of movable equipment and infrastructure is promoted. Through new technologies such as application cloud calculation, edge computing, intelligent analysis, the data cloud storage and video intelligent analysis are developed, and safety guarantee level is enhanced. 5G signal receiving functionality is equipped on Fuxing Smart EMU, meeting the live broadcasting demand of Olympic games. Since the launch of Beijing-Zhangjiakou Smart High-speed Railway on 30 December 2019, high-speed railway ATO system is operating stably, gaining positive feedback from users.

On the Olympic branch line of urban rail transit Line 11, new technologies including FAO virtual flexible marshalling, active obstacle detection will be tested. By adapting train operation and revising train operation plan to meet passenger flow demand, the flexibility in directing train operation is elevated, as well as rail transit traveling convenience for passengers.

The internetized, intelligentized, and low-carbonized rail transit is providing safe, convenient, efficient, green, economical traveling services, reshaping the traveling habits of passengers. The Beijing-Zhangjiakou-Yanqing rail transit network is presenting an unprecedented and immersive experience at the Beijing Winter Olympics.

(Translated by ZHANG Liman)