时　评

关于城市轨道交通网络的总体研究

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随着我国城市化进程的高速推进和大城市轨道交通的快速发展，轨道交通已经成为城市交通的骨干。由于城市化进程中流动人口增加、工作地与居住地分离，造成交通出行量大且存在较大的不确定性，再加之轨道交通线路潮汐特征明显、客流不均衡系数大，因此许多线路采用传统运营方式运能难以满足客流（尤其是超高峰客流）需求。运营模式必须采用一种更灵活、更高密度的运输组织方式，而高密度运营又需要更稳定、更高可靠性的设备为其提供技术支持。

笔者认为，应从以下四个方面开展城市轨道交通网络的总体研究：

一是创新长大线路的运营组织方式。对于长大线路，列车走行时间完全覆盖客流超高峰时段。传统运营方式是在早高峰前按早高峰运行图形成运行方案，时间长且在过程中运能浪费大，受折返能力制约，运能难以满足超高峰客流需求。采用上、下行独立的单线运营思维来设计的运输组织模式，是以超高峰客流为导向，通过插车和远端收车的方式，突破折返制约形成以线路单向运营为特征的、覆盖超高峰客流时段的高密度行车方式，可实现高峰时段局部区段、连续超高密度行车。

二是打造无救援列车，实现无故障运行。在高密度行车条件下，车辆可靠性是关键影响因素。提升可靠度一要以提升运行韧性为导向，对涉及行车的关键电路、气路通过双备份、旁路等方式开展冗余设计，打造无救援列车，同时探索对具备独立控制逻辑子系统的融合集成；二要利用列车动态运行属性，将车辆打造成设备移动监测平台，对周边接口专业设备状态进行实时感知，实现无故障运行。

三是打造“无感运行”的信号系统。信号系统作为运营的核心系统，一要掌控设备状态，形成高冗余、高可靠、高安全的信号系统，应对超高密度网络化运营需求；二要以设备状态的全生命周期管理为目标，构建与之相匹配的运维模式，以设备状态的精准研判动态调整维护策略。

四是推进车站机电的区域化集成管控。传统的网、线、站管理架构，是以专业分工为基础的。随着网络化发展以及信息化数字化技术的进步，打破传统机电专业子系统的封闭孤岛、实现系统集约化设计与集中管理已成为可能。利用云 & 物联网技术将各专业的设备层、各级控制层和应用层（前端界面）解耦合，保留设备层，将各专业的各级控制和应用集中融入平台。平台采用云边一体化的结构，在车站设边缘控制器，其他在云端。平台具有远程控制多线路机电设备的能力，从而使各专业独立运维转变为区域化集中统一运维。这种模式将大幅提升设备管理智能化效能和可靠性水平，降低现场人员数量及专业能力要求，提升设备的通用性，从而大幅降低运维成本。

Commentary

General Study on Urban Rail Transit Network

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With urbanization progress rapid advancement and urban rail transit fast development in major cities in China, rail transit has become the backbone of urban transportation. Due to floating population increase and workplace/residence separation in the urbanization process, transportation volume becomes enormous, possessing huge uncertainty. Additionally, rail transit lines exhibit significant peak-hour traffic patterns and passenger flow imbalance coefficient is large. As a result, many lines that adopt conventional operation management mode find it challenging for their transport capacity to meet the transportation demand (especially the super-peak hour passenger flow). A more flexible high-density transportation organization mode is needed for operation, and high-density operation requires more stable and reliable equipment to provide technical support.

Author believes that the general study of urban rail transit network should be carried out from the following four aspects:

First, innovate operation organization modes for long-large lines. Train travel timespan of long-large lines covers the entire

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passenger flow super-peak hours. The conventional operation mode involves devising operation timetable according to morning peak-hour operation diagram before morning peak hours, which is time-consuming, and the transport capacity during the process is wasted. Constrained by train turn-back capacity, the transport capacity can't meet the super-peak hour passenger flow demand. By adopting a transportation organization mode that employs independent single-line operation for both up and down directions, oriented by super-peak hour passenger flow, the continuous high-density train operation through specific intervals during peak hours is achieved by the insertion and withdrawal of trains at remote terminals, breaking the constraints imposed by train turn-back, forming a high-density train operation mode that features one-way operation and covers passenger flow super-peak hours.

Secondly, establish a rescue-free train system for fault-free operation. Under conditions of high-density train operation, vehicle reliability is a critical influencing factor. To enhance reliability, it is necessary to focus on improving operational resilience. This can be achieved by implementing redundant design such as dual backup and bypass for critical circuits and pneumatic systems involved in train operation. Thus, a rescue-free train system is built, and the integration of independent control logic subsystems are explored. Additionally, by utilizing train dynamic operation characteristics, vehicle can be transformed into a mobile equipment monitoring platform, providing real-time recognition of the status of surrounding interface devices, thereby achieving fault-free operation.

Thirdly, build 'seamless operation' signaling system. As the core system of operation, the signaling system needs to have high redundancy, high reliability, and high safety to meet the demands of high-density networking operation. It should regard equipment status full life cycle management as the goal and establish corresponding maintenance mode, enabling precise assessment of equipment status and dynamic adjustment of maintenance strategies.

Fourthly, regional integration and control of station electromechanical systems should be promoted. The conventional management framework of network, line, and station is based on specialized disciplines. With the development of networking and informatization digital technologies, breaking the isolation between conventional electromechanical subsystems and achieving system integration and centralized management has become possible. By utilizing cloud and Internet of Things (IoT) technologies, the equipment layer, control layers at various levels, and application layer (front-end interface) of each discipline can be decoupled, with the equipment layer retained, and the control and application layers of each discipline integrated into a platform. The platform adopts a cloud-edge integrated structure, with edge controllers installed at the station and others on the cloud. The platform has the capability to remotely control electromechanical equipment across multiple lines, transforming independent maintenance by each discipline into regional integrated and centralized maintenance. This mode will significantly improve the efficiency and reliability level of equipment intelligentized management, reducing the number of on-site personnel, lowering requirements on their specialized abilities, enhancing equipment versatility, thereby substantially reducing maintenance costs.

Translated by ZHANG Liman

世界上最拥挤的地铁系统

我国北京、上海等城市地铁的拥挤程度已经让人觉得不可思议了，但是世界上最拥挤的地铁却并不在中国，而在日本东京。东京地铁的建设比较早，东京是亚洲第一个建造地铁的城市，东京地铁的线路总里程约为304.1 km(2020年统计数据)。

东京地铁包括13条线路(东京Metro地铁共9条线，都营地铁共4条线)，建有285座车站，相比世界著名的纽约地铁的472座车站，还有中国北京地铁的428座车站(截至2020年12月)，东京地铁的车站数量并不算多。所以，其拥挤程度可想而知，挤完东京地铁再看北京、纽约地铁的拥挤程度，那真是小儿科了，敢在高峰期去挤东京地铁的人，都是“勇士”！东京地铁是全球客流量最大的地铁系统，也是最拥挤的地铁系统。

东京是日本的政治、经济和文化中心，也是世界上最繁华的城市之一。但是，与纽约相比，东京的土地面积要小得多，人口也更为密集，因此，地铁的压力就更大，拥挤程度位居世界第一也就名副其实了。回望历史，东京的地上轨道交通建设大约始于1872年。1917年，早川德次提出修建地铁的申请。1927年12月，东京开通了第一条，亦是亚洲第一条地铁运营线路——银座线上野－浅草段。这条线路不仅改变了东京人的生活方式，还使人们的活动空间和范围不断扩大。1940年，已基本完成了这座城市目前的所有地上轨道交通网络。

随着东京轨道交通建设的发展和推进，“以车站为中心，建立起商圈，慢慢发展为城市中心”的模式使得东京逐步出现了像新宿、涩谷这样的副中心。如今，东京的轨道交通在公共交通分担率中所占比重已超过70%。

(来源:《轨行致远》)