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About calculation and research on the capacity of receiving and sending vehicles in the depot of zigzag access section of urban rail transit

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Abstract: The paper utilizes the time interval method and simulation technology to analyze and compute the throughput capacity of urban rail transit (UTO)：Unattended Train Operation) lines, thereby presenting a novel operational solution for UTO mode in our country. Additionally, it introduces a fresh perspective and methodology for rail transit operation.

Keywords: Depot; Zigzag; Entrance and Exit Lines; Transit-receive

1. Introduction

As is widely recognized, rail transit serves as the predominant and future-oriented mode of modern urban transportation. According to data from the China Urban Rail Transit Association, as of December 2022, the operational length of urban rail transit lines in China has surpassed 10,000 km, reaching a total of 10,199.5 km. Based on incomplete statistics, there are currently 384 vehicle bases and depots in operation nationwide for rail transit systems, among which a significant proportion have been utilized for TOD comprehensive property development or reserved for potential TOD conditions.

The layout and construction of rail transit depots are influenced by various factors, such as urban planning, land use conditions, and station positions. In the new stage and situation of urban development, depots are no longer solely limited to meeting operational and maintenance needs; they also undertake additional economic enabling functions. To achieve these functions effectively, a well-designed and strategically positioned depot is essential. However, seamlessly integrating the exit line with the station poses the most critical challenge in realizing these functions. Only by addressing this aspect proficiently can the operational efficiency and economic enabling potential of rail transit depots be fully realized.

The entrance and exit line of the depot serves as a crucial passage for rail transit trains to access and depart from the main line. Traditionally, the connection scheme for the exit line mostly adopts either two separate lines or a splay line in a “2+1” conFigureuration. The practicality of this traditional integration scheme has been extensively verified during periods of low train automation levels. However, with advancements in intelligence and wisdom within rail transit systems, an increasing number of cities have adopted higher levels of automation such as GoA3 or GoA4 UTO/FAO automatic driverless modes. In light of this new situation, it is imperative that car depot layout plans are coordinated with the development of green and intelligent rail transit while aligning with more detailed updates in urban planning to better empower urban development. Therefore, there is an urgent need to explore and implement new yard layout plans.

2. New “Zig-Zag” exit line solution and significance

2.1 New Zig-Zag exit line introduce

The research delves into the receiving and departing capacities and characteristics of a rail transit depot under construction in Zhejiang Province. The subway depot adopts the fully autonomous UTO mode, while implementing an innovative “zigzag” exit line scheme. The scheme makes the subway depot and the station form a forward, parallel type, and close adjacent., connecting the exit and entry lines through the turnout of adjacent stations after the station, with interconnection facilitated by a cross-crossing line. Please refer to Figureure 1 for a schematic diagram illustrating the relationship between the station and the depot, see Figure.1.

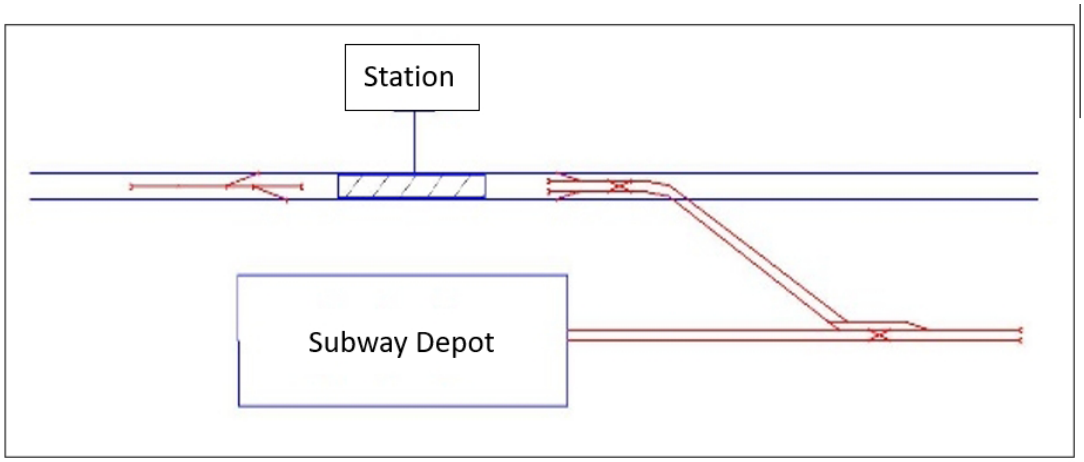

Figure.1 Schematic diagram of the exit and entry line of the depot

The scheme is characterized by the use of a font for the exit and entry lines, In the scheme, there are two inbound & outbound sections on the east side of the subway depot. It is used for sending, receiving and returning trains between the main line and the field section.

2.2 The significance of the zigzag exit line adopted by the depot

In general, in the case of the above, the traditional design of the exit and entry line uses the light bulb line to circle and cross a large of economic benefit land, and away from the station design. However, the development of fully automated unmanned UTO intelligent rail transit provides the possibility and conditions for the realization of the new entry line that is the zig-zag type. This solution can not only greatly shorten the length of the entry line, but also make the overall layout of the depot more compact, occupy less area, and the project cost is relatively low.

The most important thing is that the depot entry line is designed as a “zigzag”, and the depot and the station can be designed as a parallel parallel, so that the comprehensive development of the depot TOD and the station TOD development can be seamless, enabling the linkage development of the station, the depot and the surrounding city, improving the overall economic value, and realizing the spatial integration of the station and the city. The “isolated” TOD development of the depot is avoided, as shown in Figure.2 below.

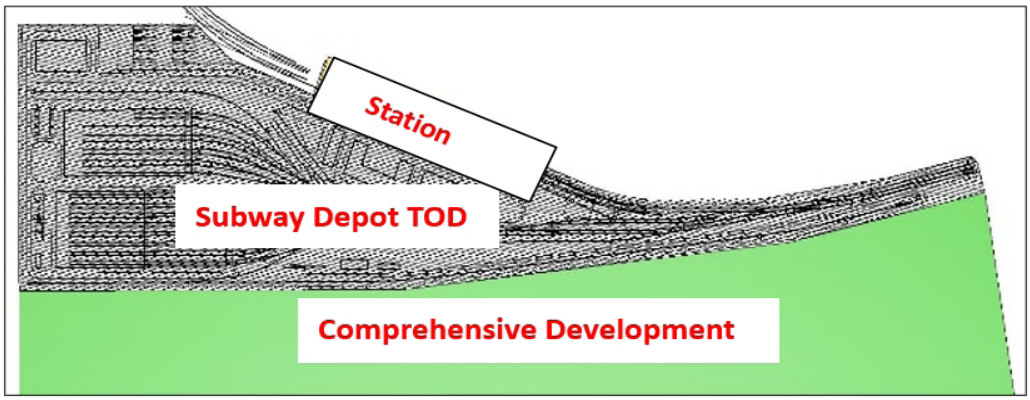

Figure.2 The relationship diagram of station, depot and comprehensive development

This new type of zigzag exit line solution has so many advantages and characteristics, However can it meet the maximum capacity needs of rail transit operating systems? This is an important and critical problem, so the author has carried out in-depth analysis and research.

3. Train receiving & departure section division of subway depot

The early operation model adopts a low level of automation, and the depot layout is also normal sequential layout, so the control fac-

tors of the vehicle depot's receiving and receiving vehicle access and access section can be divided into two control factors: intra-section time and out-section time. In the two processes, it can be divided into several zones according to the route and calculation needs.

The in-segment refers to the time required for the completion of the transfer mode from parking garage to train; Departure time refers to the time required for the converted train to enter the main line operation.

However, the depot studied in this paper is a fully automated driverless vehicle under the operation mode of high-level GoA3-GoA4 UTO under the new trend, and the exit line of the depot adopts a zigzag shape and has a return rail. Therefore, the receiving and departure sections are divided into three stages according to needs, as shown in Figure.3:

Stage 1: The train from the parking train inspection depot X1 clearing throat area X2 axle is stage 1;

Stage 2: The front enters X2 and the rear clears X3 axle for stage 2;

Stage 3: The front enters X3 until the left axle of the switch is cleared.

On this basis, the ability of sending and receiving vehicles in the depot is calculated and studied.

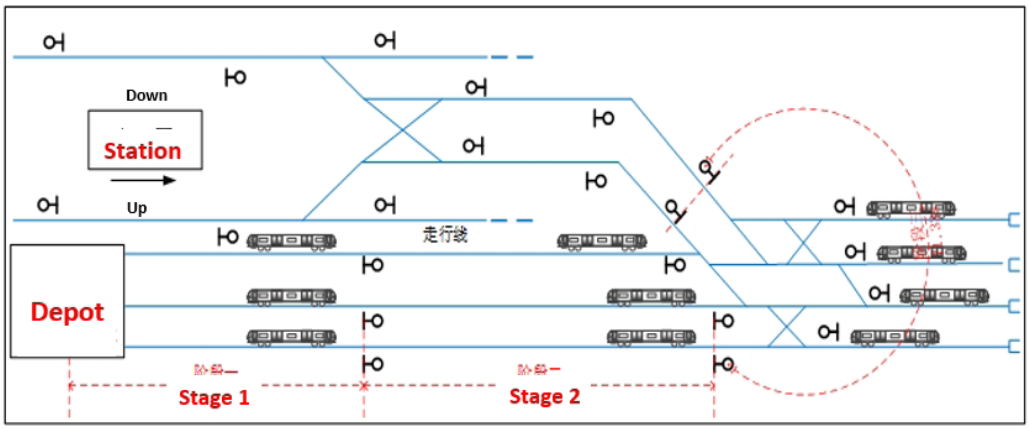

Figure.3 Train access stage division diagram

4. Calculation and analysis of train inbound & outbound capacity for deopt

4.1 Calculation and analysis of train outbound capacity

The route preparation of train departure from depot should be based on the principle of having the least number of switches and the shortest distance between trains. The above

mentioned depot has divided the departure section according to the characteristics of UTO trains of this line, so the time interval of train departure can be calculated according to the three stages respectively. The train departure means that the train starts successively from the parking building of the depot. Go through "Stage 1→ Stage 2→ Stage 3" and run successively to the normal line section. See Figure. 4 and Figure. 5 below for the specific operation route.

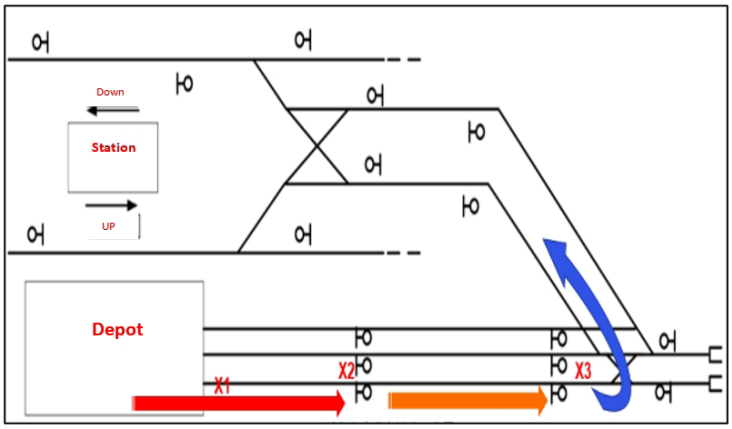

Figure.4 Train outbound route diagram

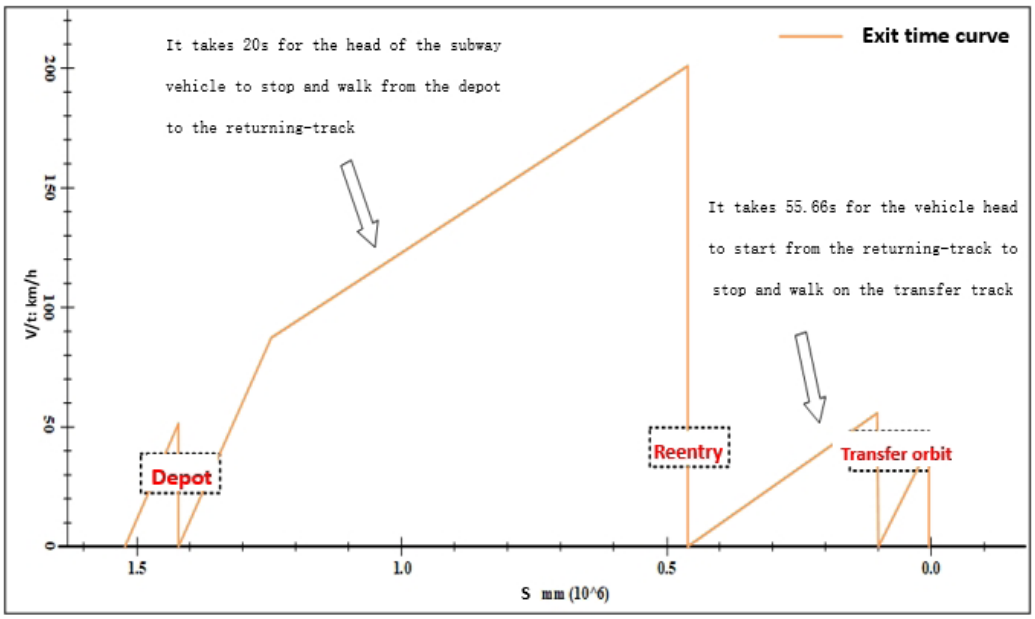

Figure.5 Train outbound route simulation calculation diagram

The train departure interval is composed of three stages, and the control time calculated by simulation is the maximum of the three stages, that is, Tmax control =113.81s, as shown in Table 1:

Exit process (parallel route according to axle point)	Signal	Time(s)	Time interval between vehicles exits (s)
a. Establish the approach of the entry section, stop to the return rail, establish the approach, and reach the axle counting point on the left side of the clear switch 2	X1	113.8	113.81
b.Enter X2 from the front and clear X3 count axle point from the rear of the train	X2	97.8	
c. Enter X3 from the front, stop to the return rail, establish an exit route, and clear the axle counting point on the left side of switch 13	X3	71.33	

Table.1 Train outbound interval analysis table

According to the simulation calculation of train route and the calculation analysis of running time interval method, it can be seen that although there are more routes in the middle section of stage 2, the time of stage 2 is not the maximum, so it is not necessary to divide stage 2 into multiple routes for research. It can be concluded that the maximum train departure interval is 113.81s.

According to the formula, it can be obtained:

p/h

Conclusion: According to the calculation of simulation method and running time interval method, the train discharging capacity of this depot is about 31.63 pairs /h, that is, the train discharging capacity of 30 pairs /h can be satisfied with the train discharging capacity of this depot.

4.2 Alalysis and calculation of train inbound capacity

The sequence of trains entering the depot and returning to the parking building is that the trains run successively from the station to the parking train inspection warehouse through “stage 3→ Stage 2→ stage 1”. The specific operation route is shown in Figure.6 and Figure.7 below:

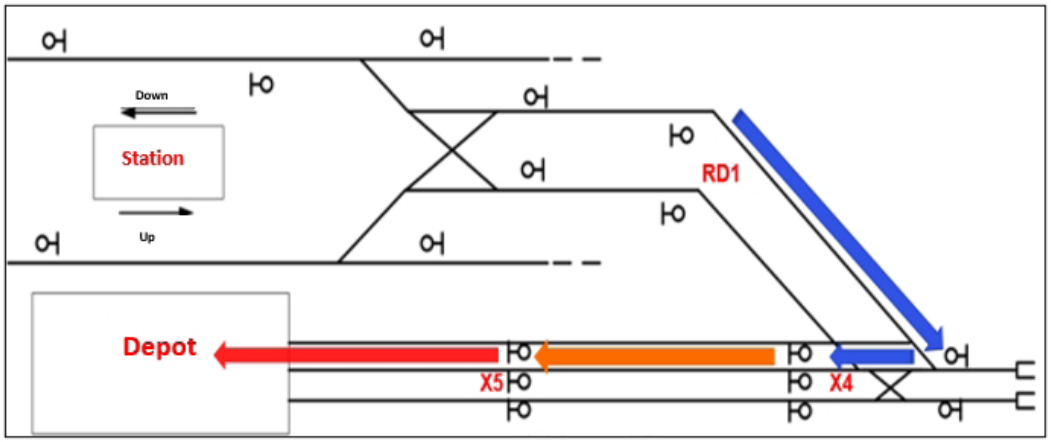

Figure.6 Train inbound route diagram

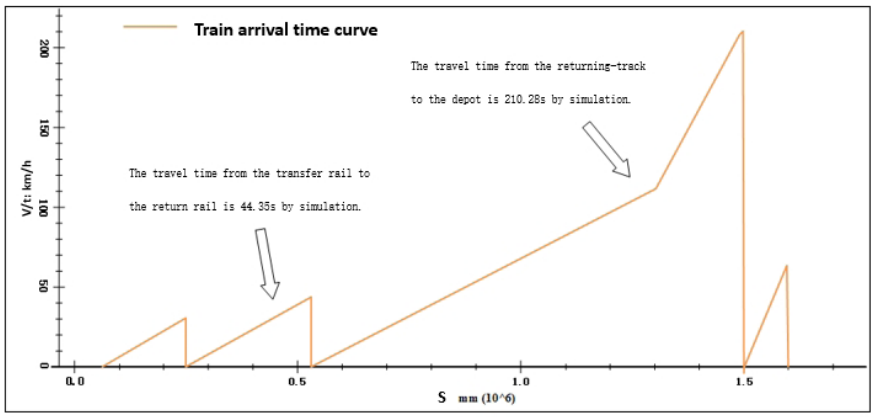

Figure.7 Simulation calculation diagram of train inbound

As can be seen from Table 2 below, the running interval of the train is composed of the following three parts: a, b and c, and the control time is the maximum of the three parts, that is, Tmax control =119.77s.

Entry process (Divide parallel routes according to axle counting points)	Signal	Time(s)	Entry interval（s）
a. Establish the approach of the entry section, stop to the return rail, establish the approach, and reach the axle counting point on the left side of the clear switch 5	RD1	95.53	119.77
b. Start from the reentry rail, clear the X5 axis point at the rear of the car, and establish the depot approach	X4	113	
c. Enter X5 from the front of the car and stop at the list check library	X5	119.8	

Table.2 Analysis table of running interval between train arrival and departure

The maximum time interval obtained by simulation calculation is 119.77s, then the capacity of train entering warehouse can be obtained according to the formula:

p/h

Conclusion: Through simulation and calculation of running time interval method, the capacity of inbound and outgoing train in the depot is 30.05 pairs /h, which can meet the demand of the maximum capacity of the system (30 pairs /h).

5. Conclusion

Under the premise of meeting the needs of vehicle operation, receipt and departure capacity and operation and maintenance, the design of car depot and access line should fully consider the important role played by car depot in the background of new urbanism, the intensive urban land, and the optimization of city-station spatial integration, so as to enable the comprehensive development economy of the city and improve the overall economic value of the region.

As a rail transit designer, we have the responsibility and obligation to organically integrate the station and the depot through reasonable access line design scheme, so as to realize the close connection between urban development and comprehensive development of rail transit. At the same time, we should actively adapt to the development needs of rail transit in the new situation, and constantly forge ahead to empower and contribute to the new development of urban economy.

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