Research Article

Quality Analysis of Railroad Train Shunting Operation Plan Using the Intelligent Body Model

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Received 14 May 2022; Accepted 23 June 2022; Published 7 July 2022

Academic Editor: Qiangyi Li

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Shunting work is an important component part of railway transport production and is an important link in realizing the train marshalling plan and the train operation map, accelerating the rotation of vehicles, and completing the task of transport production. With the present, the gradual construction of passenger dedicated lines and high-speed train operation bring a new dawn to railroad transportation on the one hand, but on the other hand, high-speed train operation makes the process of train operation more complicated, and the safety hazards and uncontrollable factors of trains are higher than before. Compared with existing lines, passenger dedicated lines put forward higher requirements on the performance of train operation and dispatching system, requiring better real-time, intelligence, and interactive response characteristics of the train operation and dispatching system. The construction of passenger dedicated lines and the increase in train operation speed have put forward higher requirements for safe, on-time, and high-efficiency train operation. The train operation scheduling system is one of the cores of intelligent railroad transportation system, which is the guarantee of safe and on-time train operation. This requires the search for new control strategies to meet the requirements of high-speed train operation and multiple objectives of safety, punctuality, and comfort. Train operation scheduling is a typical distributed system. At present, there are still problems in the safety of railway shunting operations, such as disconnection in management and implementation, failure to revise some rules and regulations, frequent occurrence of obstacles in equipment and facilities, and substandard quality of operators. Therefore, it is necessary to make a systematic analysis of the current situation of railway shunting safety and propose countermeasures and measures. By studying the structure of intelligent body and multi-intelligent body theory, it decomposes the influencing factors of railroad shunting operation, designs the intelligent body model of each element, and applies it in train shunting operation to improve the quality of railroad shunting operation.

1. Introduction

The railroad is an important infrastructure and a safe and efficient mode of transportation. Based on the original “four vertical and four horizontal,” China’s railroads have planned a high-speed railroad network of “eight vertical and eight horizontal” to realize efficient travel and transportation of domestic railroads. With the development of railroad network, the number of railroads and transportation tasks has become heavier, which has put forward higher requirements on the scheduling plan of railroad trains. Train scheduling should not only be scientifically but also reasonably arranged and have a certain foresight; everyone should know the point, line, and face. The dynamic operation is included in routine work. As the direct operation object of high-speed railroad staff, computer interlocking system and dispatching system have been widely used in China [1]. A computer interlocking system is responsible for establishing the core control equipment of railway traffic access road. The computer interlocking system realizes the interlocking control between the turnout, signal machine, and track circuit under the operation of the signal operator or ATS system, which is an indispensable guarantee equipment for safe and efficient railway driving. The dispatching system adopts decentralized self-discipline technology to realize the centralized management, unified command, and real-time.
supervision of transportation dispatching, which is in line with the development direction of travel remote command automation and is the innovation of the traditional traffic organization mode.

The shunting operation plan is a specific action plan that stipulates how to transfer vehicles and their operation procedures. Picking up and coupling trains according to station and vehicle marshalling refers to the marshalling process in which the shunting line of the shunting yard gathers the vehicles in front of the intermediate station, and then adjusts the sequence so that the trains arrive at the intermediate station in sequence. This is a very complex and important work [2]. With the progress of information technology, the traditional optimization algorithm can no longer meet the needs of intelligent development of railroad shunting work decision, and the emergence of reinforcement learning provides a new idea for this. Reinforcement learning technology is a branch of machine learning, and the behavior control of intelligent body based on reinforcement learning has become one of the hot spots of research. Reinforcement learning, also known as reexcitation learning, evaluation learning, or reinforcement learning, is one of the paradigms and methodologies of machine learning used to describe and solve the problems of agents (maximizing returns or achieving specific goals through learning strategies during the interaction with the environment). Railroad system, as a combination of multiple intelligences, can effectively solve the planning of railroad shunting operation [3]. Multi-intelligent body system (MAS) is a collection of multiple intelligent bodies, and its goal is to build large and complex systems into small, mutual communication and coordination, and easy-to-manage systems. MAS is an important branch of distributed artificial intelligence research, and its distributed processing and coordination technology has the characteristics of real time, autonomy, and adaptability, which can meet the dynamic. Therefore, many scholars have applied MAS to railroad transportation-related research [4].

Based on this background, this study proposes a quality analysis algorithm of railroad shunting operation plan based on the intelligent body model. By abstractly designing each element of shunting operation into an intelligent body model and designing the communication and collaboration mechanism among the intelligent bodies, the efficient railroad shunting operation is realized. Section 1 introduces the background and necessity of the research and the chapter arrangement of the thesis; Section 2 introduces the background of the current knowledge of railroad shunting operation and some cutting-edge research work and introduces the methodology of this study; Section 3 introduces the intelligent body of railroad shunting system and designs the multifactor intelligent body model and the corresponding communication and collaboration mechanism; Section 4 focuses on the design of the intelligent body model and the corresponding communication and collaboration mechanism. Section 4 focuses on the empirical study of railroad shunting operations using the designed dispatching intelligent body model and examines the effect of the model. Section 5 summarizes the work in this study and proposes ideas for the next step. In this paper, by studying the agent structure and multi-agent theory, the influencing factors of railroad shunting operation are decomposed, and the agent model of various elements is designed and applied to the train shunting operation to improve the quality of railroad shunting operation.

2. State of the Art

In the traditional railway transportation mode, transportation efficiency and transportation volume are the core of the model, rather than market-oriented as the key; its daily operation needs to be coordinated and managed by the three-level units of the State Railway Group Co., Ltd., the Railway Bureau, and the railway station section, and the transportation plan is formulated according to the transportation needs, which lacks timeliness, data, and accuracy, resulting in the solidification of traditional railway transportation forms and the lack of flexibility. In addition, under the traditional railway transportation model, the implementation process of the transportation plan lacks real time, cannot be dispatched and managed in combination with the actual situation, and cannot be adjusted to the plan in time, resulting in a strong lag in the railway transportation plan. China’s railroads adopt a plan-led transport organization method, which divides the whole transport process into several train operation sections, organizes full-axle grouping according to the types of trains specified in the grouping plan, and organizes train operation and cargo transportation by selecting the corresponding operation lines of the train operation chart. The daily operation of transport production is mainly accomplished through the daily (shift) plan prepared and executed by the dispatching and related personnel of the head office, road bureaus, and station sections [5]. The current transportation planning system of China’s railroads is divided into four layers, as shown in Figure 1.

At the top of the diagram is the plan at the level of capacity planning, i.e., the familiar basic train operation chart, basic locomotive turnover chart, and grouping plan. These charts are the fundamental basis of railroad transportation organization. The second level of the plan is composed of market-oriented level and maintenance oriented level. Among them, the market-oriented layer includes freight marketing plan, passenger transport marketing plan, and the preparation of locomotive and vehicle use plan (such as carriage use plan, empty vehicle unloading, empty vehicle adjustment, heavy vehicle handover, station truck entrance, and exit division and truck handover, truck utilization index and truck passenger capacity use, locomotive operation index); maintenance-oriented plans are formulated by the equipment management department, mainly including line, signal, locomotive, and vehicle maintenance plans. The third level is the daily transportation production organization and dispatching command, that is, the dispatching plan, which refers to the daily rolling preparation of dynamic factors such as trains, locomotives, vehicles, construction, and maintenance, and the formulation of transportation plans by the dispatching departments at the head office and the railway bureau according to the changes in working
conditions and needs. The types of scheduling plans mainly include four categories: freight work plan, train work plan, locomotive work plan, and construction day plan [6]. The fourth level of planning is the third level of scheduling. The fourth level plan is an extension and refinement of the third level scheduling plan, which is the so-called execution-oriented plan, mainly including station freight plan, station operation plan, station-level train operation adjustment plan, locomotive section operation plan, vehicle section operation plan, station-level maintenance plan, and construction plan. The fourth level plan is prepared and managed by the dispatching posts of the station section, which stipulates the specific contents of station operations for a certain day, a certain shift (12 hours), and a certain phase (3 hours) and guarantees the realization of the production targets stipulated by the dispatching plans of the head office and the road bureau.

Railroad grouping stations are generally equipped with relatively complete shunting yards and shunting equipment and are the main body of the railroad scheduling operation plan. It is mainly responsible for the arrival, disassembly, grouping, and departure of cargo trains, through train operation and other train operations [7]. Thus, the main work of a grouping station is to provide the train service, as shown in Figure 2.

Vemazza proposed an intelligent approach to train operation scheduling based on MAS [8]. Biedebick C, Suhl L studied the scheduling problem based on the intelligent body theory, taking German railroads as an example, with the aim of reducing the waiting time of passengers [9]. Biedebick C, Suhl L design simulation of train operation process using MAS based on real data of Indian Railways to minimize train delays [10]. Zhu Taomei, Mera Jose Manuel, and Suarez Berta use intelligent body technology to develop a railroad station scheduling aid decision system to solve the problem of organizing station operations in the presence of train delays and conflicts [11]. Du Yanhua and Ye Yangdong proposed a Petri net model for distributed railroad operation simulation system and built a multi-intelligent body-based railroad operation simulation system [12]. Wang Honggang used MAS theory to develop railroad operation scheduling system, designed the structure of railroad bureau intelligences and station intelligences on the basis of dividing static and dynamic transportation environments, and gave rules for intelligences to follow and negotiation methods between intelligences [13]. Liu Jun designs an operation scheduling system based on decentralized self-regulation, defines and explains the structure, knowledge expression, and reasoning methods of each intelligent body, and proposes a decision system consisting of a five-layer network for solving railroad operation scheduling problems [14]. Chen Xiaowei and Shen Chenglu use CAN bus technology and industrial Ethernet technology to realize a distributed computer interlocking system integrating signal machine intelligent body, turnout intelligent body, and section intelligent body [15]. Taking Beijing South
Station as an example, Chunxia Gao constructs a pedestrian traffic microsimulation system for passenger hubs including passenger intelligence, facility intelligence, management intelligence, and data management intelligence and analyzes the congestion points and congestion propagation process in the hub [16]. Wei Wenjun combines the intelligent body technology with the all-electronic execution unit, designs an all-electronic intelligent distributed emergency interlocking system, and uses a fault tree approach to identify system risk sources [17]. Therefore, by studying the agent structure and multi-agent theory, this study decomposes the influencing factors of railway shunting operation, designs the agent model of each element, applies it to train shunting operation, and improves the quality of railway shunting operation.

3. Methodology

3.1. Shifting Operation Influence Factors and Indicators

3.1.1. Influencing Factors of Shunting Operations. The influencing factors of the efficiency of shunting locomotives mainly involve three aspects: (1) the workload statistics of shunting locomotives; (2) factors for improving the efficiency of shunting locomotive operations; and (3) the same caliber shunting locomotive benefit evaluation factors. The main function of the grouping station is to unpack the train and shunting operation. The shunting operation can be divided into transit selective shunting and station operation shunting, the latter is mainly the station loading and unloading car pickup and delivery and vehicle delivery and repair; compared with transit selective shunting, group number information is not obvious, and shunting operation efficiency directly affects the station follow-up production and other characteristics. The former is according to the station stage plan, train grouping plan, now the car and traffic succession, etc., to complete the corresponding shunting operations [18]. The former is to complete the corresponding shunting operation according to the station stage plan, train grouping plan, present train, and traffic succession. Among them, the most difficult shunting operation is to pick up the train; although there are scholars in China to study the problem, the actual production of
shunting decision model and system is less. According to the intelligent body model, the shunting intelligent command system constructed in this study can realize the automatic preparation of shunting hook plan for picking up trains, effectively reducing the number of shunting hooks, and improving operation efficiency.

(1) The Number of Lanes and Fixed-Use Program of Shunting Yard. The actual situation on site is that the number of lanes is smaller than the number of groups of going groups, and the number of lanes is even more insufficient after considering the regional traffic (pickup traffic) and local traffic going, so the traffic of different groups often needs to be assembled in mixed lines. After that, the workload is directly influenced by the composition of mixed traffic. The larger the difference between the general number of lanes and the number of groups, the more serious the mixed line situation, and the more difficult the grouping.

(2) Technical Specification Requirements. To ensure the safety of the vehicle cargo loading and train operation, the rules for the management of railroad dangerous goods transport more detailed provisions of the vehicle grouping isolation requirements. These vehicle isolation requirements and the existence of closed cars in the flow are to be compiled, to add new constraints on the vehicle grouping.

(3) Train Grouping Plan. In the train grouping plan and daily shift plan of the station, the proportion of trains to be removed and their requirements for listing directly affect the size of shunting operation. Compared with direct trains and section trains, its unpacking requirements are more flexible, because the use of the line and the direction of the vehicles to be compiled are not fixed, and there are higher requirements for the shunting system.

(4) Line Capacity. The limitation of the number of line capacity increases the difficulty of shunting so that the original can be in the selection of the same line in the editorial traffic that had to be split into two or several groups of cars, disrupting the overall layout and increasing the amount of additional shunting operations.

3.1.2. Analysis of Optimization Indicators for Shunting Operations. There are two main indicators to measure the quality of shunting operation plan, namely the number of shunting and balanced utilization of the train track.

The number of shunting is a time-consuming and labor-intensive task, and the shunting drivers in the station have to travel frequently to and from each unit, so the higher number of shunting will greatly increase the labor intensity of the drivers; the fewer the number of times and the more balanced the inventory utilization rate, the better the quality of the shunting operation plan; secondly, as the shunting will occupy key resources such as the station throat area, it will inevitably have an impact on the maintenance capacity of the station [19]. The shunting work in the station mainly comes from two aspects, one is the shunting in and out of the station, and the other is the shunting of the station. It is unavoidable to transfer trains in and out of the station, so reducing the number of transfers is the key to optimize the shunting operation plan.

The total length of time covered by the shunting operation plan is \( L \). If the length of the time slice is \( \Delta L \), any one of the stock can be divided into parts according to the number of time slices, which can be expressed as follows:

\[
I = \frac{L}{\Delta L}.
\]

(1)

The total number of strand lanes used can be set using the following method. \( f^k_i \) is defined as the length of time that the \( i \)th time slice on the \( k \)th strand is occupied, and then, the average utilization of the strand is as follows:

\[
\bar{\mu} = \frac{\sum f^k_i}{n_j L}.
\]

(2)

The variance of the stock channel utilization was as follows:

\[
\sigma = \frac{1}{n_j \cdot I} \sum_i \sum_k \left( \frac{f^k_i}{\Delta L} - \bar{\mu} \right)^2.
\]

(3)

The smaller the value of \( \sigma \), the better the quality of the shunting plan. That is, the smaller the variance of the utilization rate of all the 1 time slices, the more it meets the requirement of balanced use of the lanes: both to meet the balanced use of different lanes and to ensure the balance of the same lane on different time slices.

3.2. Smart Body Characteristics and Structure. The significance of the agent (MAS) model is to simplify and abstract the details of concrete things or phenomena in the real world to meet the needs of practical application or scientific research. The MAS model is a simulation model that can simulate the evolution of real things or phenomena within a certain space-time range. MAS is a multi-intelligent federation of multiple intelligences combined in some way, and the members of these intelligences coordinate and serve each other to accomplish complex tasks together. The research on MAS focuses on two aspects: individual intelligences and multi-intelligence collaboration in MAS.

An intelligent body is broadly defined as an entity with intelligence and can refer to both humans and various intelligent hardware and intelligent software. A wide range of scholars have different views on the definition of an intelligent body, and different research fields have assigned different meanings to intelligent bodies. One of the more recognized studies is that of Wooldridge and Jennings, who argue that almost all intelligent bodies have some common characteristics as follows [20]:

(1) Autonomy, the ability to control one’s own behavior and internal states without being controlled by other intelligences.
(2) Social, also known as interactive or interactional, communicating with other intelligences through some kind of language and working together to accomplish specific tasks.

(3) Reactivity, the ability to perceive the external environment and respond appropriately to changes in the environment.

(4) Proactivity, the ability to spontaneously participate in some processing or collaboration to accomplish a task. Based on the above characteristics, an intelligent body can be considered as an entity that operates in a dynamic environment, is autonomous, social, reactive, and proactive, is able to perceive changes in the external environment by itself, takes the initiative to adopt various necessary behaviors including social and other means driven by the goals, and acts the results of the behaviors on the external environment.

The individual structure of an intelligence defines and describes its internal constituents and the relationships among them. Typically, a single intelligence can be divided into three structures: reactive, deliberative, and hybrid.

Figure 3 shows a reactive intelligence. Reactive is the simplest intelligent body structure, the behavior of the intelligent body depends on the input of the external environment information from the sensing device and is triggered by the way of “stimulus a response,” avoiding complex logical reasoning, and its behavior results in a certain impact on the external environment, with the advantages of fast response and easy to implement.

As shown in Figure 4, the behavioral process of the deliberative intelligence is not a direct feedback from the sensing device to obtain information about the environment, but a decision is made after considering the external environment, internal state, knowledge base, and system goals. The deliberative structure can solve more complex problems with a certain degree of intelligence, but the disadvantage is that the decision-making process is complex and the response speed is slow.

Figure 5 shows the hybrid smart body structure, which combines the above two structures to form a hybrid smart body structure. For simple and emergency situations, it is handed over to the reaction module for execution with consideration of speed priority, while for general and complex situations, it is handed over to the decision module for execution with consideration of intelligence priority. The hybrid intelligence combines the advantages of both structures, but the trade-off between the familiarity and responsiveness of the intelligence is an important consideration in the design process.

3.3. MAS Architecture. With the development of network and computing technology, some real systems are often exceptionally complex, large, and have distributed characteristics, and individual intelligences are unable to do so due to the limitations of their own capabilities, so the study of multi-intelligence is gradually becoming a hot topic. MAS has the following characteristics: the intelligences are autonomous and independent and can make decisions individually to solve specific problems; the data are distributed among the intelligences; the control is distributed among the intelligences; when the information is incomplete, the individual intelligences also have processing capability: centralized, distributed, and hybrid.

The centralized structure is shown in Figure 6, in which the management intelligences have global knowledge through which they achieve local control of their management scope, while the slave intelligences are the specific executors of control. The centralized structure is characterized by the ability to maintain a high degree of internal information consistency and easy management and control of system members. However, as the number of slave intelligences increases, the management intelligences will become the bottleneck of the whole system.

The distributed structure is shown in Figure 7, where the status of each intelligence in the system is completely equal, and the behavior of the intelligence depends on each intelligence’s surrounding environment, its own condition, and the information of interaction with other intelligences. The distributed structure does not have control bottlenecks and has the advantages of stability and flexibility, but it is more difficult to achieve coordination within the system.

The first two structures are fused to form the hybrid structure shown in Figure 8. The hybrid structure generally consists of multiple groups, and the management intelligences of each group are equal to each other. The hybrid structure balances the advantages and disadvantages of the above two structures and has a dynamic and open character.
MAS works by combining a series of dispersed intelligent units according to a certain architecture and solving complex problems through communication and tithe among the intelligent units. Each intelligent body is an independent individual with its own goals and behavioral guidelines, and although individual intelligent bodies can make their own decisions, they cannot solve the global problem. As shown in Figure 9, in the process of railroad transportation organization, each station is a relatively independent individual, in a spatially dispersed layout, with different methods of operational organization, which is a typical distributed system. High-speed railroad signaling system is a complex system composed of several devices, and the functions among each device are relatively independent, but need to realize the overall function through information interaction, which is very similar to the mechanism of MAS autonomy, communication, interaction, and collaboration.

4. Result Analysis and Discussion

4.1. Division of Shunting Operation Phases. Train transfer work is an important part of railway transportation production, which is an important link to realize train formation plan, train operation map, accelerate vehicle turnover, and complete transportation and production tasks. Railroad operation dispatching system is a huge comprehensive dispatching system, which involves multidisciplinary system engineering such as transportation organization, rolling stock, communication signal, power supply, safety monitoring, and maintenance rescue. The comprehensive dispatching system consists of comprehensive dispatching center, station system, and basic network equipment. This system includes eight functional subsystems such as train operation dispatching, transportation plan management, rolling stock dispatching, passenger service, power dispatching, comprehensive maintenance, crew dispatching, and safety monitoring. The train operation dispatching simulation subsystem is a core subsystem of the integrated dispatching simulation system.

To solve the train scheduling problem, it is also necessary to make a certain transportation plan, and the train operation dispatching simulation subsystem is mainly used to solve this problem. The stage plan is sent from the dispatcher to the station intelligence through the management intelligence, and the station watchman is only the executor of the plan and has no right to make changes to the plan content. However, for shunting operation, the station duty officer is
both the maker and the executor of the plan, and the reasonable degree of shunting operation plan preparation determines whether the station operation can be carried out in an efficient and orderly manner. The amount of shunting operation of high-speed railroad is less than that of existing line, but the density and speed of trains are high, and the requirement for punctuality is strict. The unreasonable shunting operation plan is likely to lead to late trains, and when the situation is serious, the late phenomenon will affect other stations and trains on the line and may even lead to train and shunting conflict accidents.

In the actual production process, in addition to guiding pickup and departure, whether it is train operation or shunting operation, the process of occupancy of the approach needs to go through three stages: approach locking, automatic segment unlocking, and complete unlocking of the approach.

4.2. Intelligent Body Behavior Constraints. To ensure safe, efficient, orderly, and punctual train and shunting operations at the station, the objective function is set to minimize the difference between the actual start and end time of shunting operations and the planned time under the premise of ensuring that the stage plan is not affected. To ensure that the subsequent operations are not affected, the requirements for the end time of the operation are usually higher than the
start time, and this is differentiated by setting the penalty cost.

\[ \min Z = \sum_{t \in T} \left[ c_x \sum_{i,j \in A} rot(f) - ot(f) + c_y \sum_{i,j \in A} rdt(f) - dt(f) \right]. \quad (4) \]

(1) Feeder locking and unlocking time constraints:

\[ rot(f) = \sum_{t \in t'} t \times x(f), \quad \forall f \in F, (i, j) \in R, t, t' \in T, \quad \] (5)

\[ rdt(f) = \sum_{t \in t'} t' \times x(f), \quad \forall f \in F, (i, j) \in R, t, t' \in T. \quad (6) \]

Constraints (5) and (6) are used to describe the actual locking and unlocking moments of the short transfer car approach.

(2) Inlet occupancy state constraint:

\[ p(i, j, t) \geq p(i, j, t - 1), \quad \forall f \in F, (i, j) \in R, t, t' \in T, t \geq 1, \quad \] (7)

\[ q(i, j, t) \geq q(i, j, t - 1), \quad \forall f \in F, (i, j) \in R, t, t' \in T, t \geq 1. \quad (8) \]

(3) Prohibition of approach constraints:

\[ \sum_{t} x^{i,j}_{i,j}(f) + \sum_{t} x^{k,l}_{i,j}(f) \leq 1, \quad \] (9)

\[ rdt(f) = \sum_{t \in t'} t' \times x(f), \quad \forall f \in F, (i, j) \in R, t, t' \in T. \quad (10) \]

Constraint (9) ensures that the shunting operation can be continued according to the short shunting route, and there will be no turn back operation.

(4) Zone conflict constraints:

\[ y_{f}(i, t) = 1, \quad \forall f \in FT, i \in N - N D, t \in TS(f), \quad (11) \]

\[ \sum_{f} y_{f}(i, t), \quad \forall F \cup FT, i \in N - N D, t \in T. \quad (12) \]

Constraint (10) ensures that when the train plant in the phase plan occupies block point i at moment f. Constraint (11) ensures that any block point can only be occupied by one train or shunting operation at any moment at the same time.

To describe the moment of locking and unlocking of the approach, 0–1 variables p and q are established. Constraints (7) and (8) ensure that the same set of 0–1 variables for the shunting plant can only change once over time and can only change from 0 to 1, thus ensuring that the state transition from “not yet occurred” to “already occurred” for the approach locking or unlocking event can only occur at most once. The state change from “not yet occurred” to “already occurred” can only occur at most once. It is influenced by the shunting f, the approach (i,j) at t=6 moment locked, and then at t<6 p=0 and t≥6 p=1. At t=9 moment, the approach is completely unlocked and then at t<9 g=0 and t≥9 g=1.

In a multi-intelligence railroad train shunting operation, each intelligence can complete its respective task quickly; i.e., it takes the least amount of time to reach the end point. From the perspective of the reward function, it can be understood that the more rewards and fewer penalties an intelligence obtains in each round, the better the training effect is. From the formula, we can see that the time consumption will be reflected in the reward value at the end of the round for a certain Rtarget, so we use the average reward value obtained by the intelligences in each round as the evaluation criterion of the training effect, i.e.,

\[ R_{mer} = \frac{1}{N} \sum_{i=0}^{N} \sum_{step} R^{i}_{step}. \quad (13) \]

When the number of training rounds of different algorithms reaches a certain amount, their average round reward values are compared, and the trend of the reward value can reflect the convergence speed of the model, and the size of the reward value after the final stabilization can reflect the advantages and disadvantages of the learned scheduling strategy.

4.3 Example Analysis of Shunting Operation. The small-scale example is designed to optimize the 1-hour shunting operation plan in the downstream throat area of station A, which is used to verify the correctness of the model. The time interval of the example is 60 minutes, and each time interval is 1 minute. The information of train approach and arrival time in the stage plan of station A is shown in Table 1, and the information of shunting operation plan is shown in Table 2. The start time penalty cost q = 1 end time penalty cost G = 2 are set, and the running time of train and shunting in each track circuit section, zf = 1, for the convenience of calculation is set. According to the automatic station autoregulator, the train approach locking moment is determined by triggering the train approach. According to the field research results, the train set automatically triggers the inbound approach 8 minutes in advance, and the outbound approach is automatically triggered 2 minutes in advance after the train stops, and the passing train is not considered in the calculation example, and the shunting operation starts immediately after the station arranges the shunting approach.

The results obtained using GAMS optimization software are shown in Table 3, with the objective function value equal to 16. The results are verified to be in accordance with the constraints listed in the model, and the conflicts between trains and shunting, shunting, and shunting operations in the station throat area are solved.

The objective function of the model is to minimize the difference between the actual start and end time of shunting operation and the planned time. If the operation starts earlier, due to the limitation of the objective function, even if
the conditions of long shunting approach are available, the phenomenon of waiting in the middle of shunting will still occur.

The experimental results also show that the scheduling intelligence with the learning mechanism and the scheduling intelligence without the learning mechanism have almost the same efficiency at the beginning of the system operation; i.e.,

![Figure 10: Comparison of shunting intelligences with and without learning mechanism.](image)

the time to generate scheduling solutions is similar. As the system runs longer, the time required for the scheduling intelligence with learning mechanism to generate scheduling solutions is about one-half of the time required for the scheduling intelligence without learning mechanism to generate scheduling solutions; i.e., the efficiency is doubled. The similar time required for both intelligences to generate
scheduling solutions in the early stage of system operation is due to the inexperience of the scheduling intelligence with the learning mechanism, as shown in Figure 10.

5. Conclusion
In the face of the changes and development of China’s economy and the Internet, to improve the railway transportation capacity, it is necessary to optimize the mode of railway transportation, establish and improve the railway transportation service system, and increase the proportion of heavy-duty trains; it is necessary to base ourselves on the market orientation, comprehensively analyze the factors affecting railway transportation, and enrich the railway transportation cargo system; we must fully tap the capacity of railway transportation hubs, adjust the mode of transportation organization, form a modern railway freight center, and promote the sustainable development of railway transportation. In this context, this study studies the structure of the intelligent body and its application of the theory of multiple agents in the scheduling of train operations. MAS theory and organizational structure, train operation dispatching theory, and a train operation dispatching intelligent body structure with learning mechanism are proposed, and it is verified through simulation that the train operation dispatching intelligent body with learning mechanism is more efficient than the train operation dispatching intelligent body without learning mechanism.

Data Availability
The labeled data set used to support the findings of this study is available from the corresponding author upon request.

Conflicts of Interest
The authors declare that they have no conflicts of interest.

Acknowledgments
This work was supported by the Beijing Jiaotong University and China Communications Press Co., Ltd.

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