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Selection and Research of Resource Allocation Scheme for Shuttle Transport Based on FlexSim

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Abstract. Against the backdrop of the rapid development of the shuttle transport industry, the selection of car transporters and resource allocation has become the focus of enterprises. Based on the actual operations of FAW Logistics Company, we used FlexSim simulation software to construct a highly realistic shuttle transport model. This model conducted a comprehensive simulation analysis of the performance of three mainstream car transporters over an 8-kilometer shuttle transport route. Through detailed mathematical processing, we derived the optimal scheme with the lowest procurement cost. This scheme was not only validated through FlexSim simulation but also provided a feasible solution for car companies in selecting car transporters and allocating resources in shuttle transport, with significant theoretical and practical guiding significance.

Keywords: FlexSim, shuttle transport, resource allocation, car transporter

1. Introduction

A review of domestic scholars' research on FlexSim simulation software reveals that their focus has primarily been on optimizing and improving warehousing systems, pharmaceutical logistics systems, and express sorting systems, with less attention paid to the issue of resource allocation in shuttle transport. In the field of shuttle transport, the selection and configuration of car transporters urgently need to be addressed due to the pressing need for efficient utilization of transport capacity and minimization of transport costs. This paper, in conjunction with the fixed daily shuttle transport volume of 2880 units for automobile companies, uses FlexSim simulation software to model and simulate the 8-kilometer shuttle transport process of three types of car transporters. The selection and resource allocation of the three types of car transporters were derived through mathematical calculations. This method is more convenient and practical compared to other methods in solving such issues.

2. Problem Description and Optimization Objectives

2.1. Problem Description

This study focuses on the 8-kilometer shuttle transport segment from the vehicle loading area in a smart logistics park of an automobile company to the railway freight station. The annual shuttle transport volume of this automobile company in the Changchun area is 720,000 units, with 250 working days per year and a single day shift of 10 hours per day. It can be calculated that the dedicated channel in the Changchun area needs to complete the shuttle transport of 288 vehicles per hour. The specific transportation business model is shown in Figure 1:

Figure 1. Overall Process of Vehicle Transport

This paper designs three transportation schemes for this segment to explore the goal of minimizing costs under the condition of maximizing transport capacity. The first scheme involves L3-level automated heavy trucks with double-deck trailers, referred to as DMU1. The second scheme also involves L3-level automated heavy trucks with double-deck trailers, referred to as DMU2. The third scheme involves L4-level automated tractors with single-deck flatbeds, referred to as DMU3 [3]. The specific parameters of the three schemes are compared in Table 1.

Table 1. Comparison of Environmental Parameters for Three Schemes

Environmental Parameter	DMU1	DMU2	DMU3
Car Transporter Speed	40km/h	30km/h	15km/h
Loading Capacity	6 vehicles	9 vehicles	6 vehicles
Round-trip Distance	16km	16km	16km
Round-trip Time	24min	32min	64min
Loading Time	45min	68min	45min
Unloading Time	15min	23min	15min
Car Transporter Price	1.2 million CNY	1.5 million CNY	1 million CNY

2.2. Model Assumptions and Optimization Objectives

To simulate the shuttle transport process of this automobile company, the model will equivalently represent the car transporter's driving speed over a certain distance as the time taken during the shuttle transport process [1]. The total operation time of the three schemes will be obtained through model simulation. By calculating the transportation cost of the three schemes and comparing these costs, the optimal car transporter resource allocation strategy will be explored. Before constructing the model, the following assumptions were made to eliminate interfering factors:

(1) Each car transporter is assumed to be fully loaded during transport to achieve the model's goal of maximizing transport capacity.

(2) The traffic conditions on the transport path are assumed to be stable, and vehicle transport is stable, with no consideration of unexpected situations [5].

(3) The vehicle purchase cost is assumed to remain unchanged, not fluctuating with market supply and demand or over time.

(4) The efficiency of loading and unloading is assumed to be stable, with the time required to load and unload the same type of car transporter remaining fixed.

3. Simulation Model Approach and Steps

Combining the actual business needs of FAW Logistics Company, this study uses FlexSim software to construct a simulation model that can adapt to changes in transport volume and sets operational parameters to accurately simulate the results of shuttle transport. The steps to build the model are as follows:

1) Constructing the Model Layout

This paper constructs a simulation model including key elements such as generators, synthesizers, processors, and decomposers. Based on the company's fixed daily shuttle transport volume, three different types of car transporter data were selected for simulation [8]. The specific number of transport tasks was set, and the simulation model layout was built by combining the loading and unloading efficiency of different types of car transporters [9].

2) Defining the Model Operating Process

The model simulates the entire shuttle transport process from the Changchun main plant to the railway freight station, including vehicle storage, loading, and unloading. Based on the object entity logical relationships provided by FlexSim software, the model operating process was meticulously defined, and input and output ports were reasonably set to improve the reliability of the simulation results.

3) Editing Entity Parameters

During model construction, based on the selected three different types of car transporters, and the collected key data such as loading and unloading time, transport time, and loading capacity, the entity parameters of dispatching, preparing vehicles, loading, transporting, and unloading were meticulously set in the FlexSim model to fully reflect the model's realism.

4) Running the Simulation

After completing the model construction and parameter setting, the simulation was run. Each of the three simulation schemes was simulated multiple times, recording the total running time at the end of each model run, and the average running time was taken to provide strong data support for subsequent result analysis.

5) Analyzing Simulation Results

The average running time obtained during the shuttle transport process was analyzed using mathematical formulas to derive the vehicle purchase cost for each scheme under the condition of maximizing daily shuttle transport volume. Comparative analysis was conducted, and the car transporter transport scheme with the lowest vehicle purchase cost was gradually selected [2].

4. Simulation Example and Analysis

4.1. Model Case

The parameters required for the constructed model are shown in Table 2:

Table 2: Parameter Definitions for the Model

Parameter	Meaning
P_i	Unit Price (yuan)
Q	Total Transport Volume (vehicles)
T_i	Equivalent Operating Hours (hours)
L_i	Loading Capacity (vehicles)
M_i	Hourly Transport Volume after Loading (vehicles)
N_i	Total Transport Volume after Loading (vehicles)
Y_i	Vehicle Purchase Cost (yuan)
X_i	Number of Car Transporters (vehicles)
$i = 1,2,3;$	Scheme 1, 2, 3

With the objective of minimizing transport costs, the mathematical model for shuttle transport costs is established as follows:

(1) Hourly Transport Volume after Loading:

$$M_i = \frac{Q}{T_i \cdot L_i} \tag{1}$$

(2) Transport Volume after Loading:

$$N_i = \frac{Q}{L_i} \tag{2}$$

(3) Number of Transport Vehicles:

$$X_i = \frac{N_i}{M_i} \tag{3}$$

(4) Vehicle Purchase Cost:

$$Y_i = X_i \cdot P_i \tag{4}$$

Where: P_i is the unit price, indicating the price per unit of each type of car transporter. $P_1 = 120$, $P_2 = 150$, $P_3 = 100$. Q is the total transport volume, indicating the actual number of vehicles transported by the car transporter in one hour, $Q = 288$. L_i is the loading capacity, indicating the actual cargo load of the car transporter in each transport, $L_1 = 6, L_2 = 9, L_3 = 6$. T_i is the equivalent operating hours, converting the model operating time to hours. M_i is the hourly transport volume after loading, indicating the number of vehicles the car transporter can load and transport in one hour. N_i is the total transport volume after loading, indicating the total number of vehicles transported by a specific car transporter after loading. X_i is the number of car transporters, indicating the number of vehicles required to complete the total transport volume in one hour. Y_i is the vehicle purchase cost, indicating the cost required for the corresponding number of car transporters to complete the shuttle transport.

By substituting the above parameter data into the formulas, the costs for the DMU1, DMU2, and DMU3 schemes are calculated.

4.2. Establishing the Simulation Model

The simulation model for selecting and allocating car transporter resources in the shuttle transport process of a FAW Logistics Company is shown in Figure 2. First, vehicles are taken offline at the Changchun main plant, inspected, and placed in the on-site buffer zone. The vehicle handler, via the task dispatcher, moves the vehicles to the designated location in the Changchun Smart Logistics Park. According to the order instructions, the car transporter retrieves the outbound vehicles from various storage locations in the logistics park and transports them to the Changchun railway freight station, where they are unloaded and the transporter returns [6].

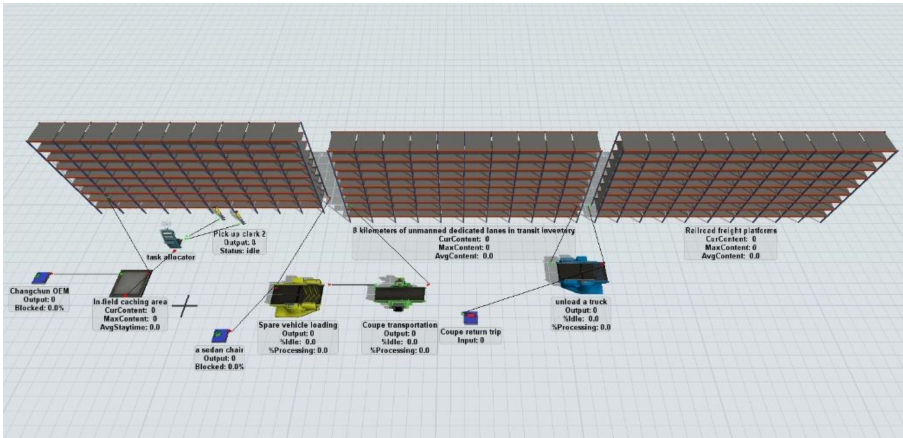

Figure 2. Simulation Model for Selecting and Allocating Car Transporter Resources

For such a complex shuttle transport optimization problem, many parameters and variables must be resolved by setting the entity object label values. The specific settings for the label values required in the simulation are shown in Table 3.

Table 3. Labels for Each Entity Object and Their Functions

Entity Object	Label	Function
Cargo	Product	Simulate the vehicle
Generator—Changchun Main Plant	Quantity	Record total transport volume
Synthesizer—Vehicle Loading	Target Quantity	Record loading capacity under three schemes
Processor—Car Transporter	Processing Time	Record vehicle preparation time under three schemes
Decomposer—Unload Vehicles	Processing Time	Record vehicle unloading time under three schemes

4.3. Simulation Experiment

To rigorously study the temporary entity operation route simulating the vehicle shipping route, each of the three simulation schemes was run multiple times, and the average running time was taken to obtain a specific running time [7].

The experimental process is described as follows:

(1) Changchun Main Plant Shipping Setup

Set the generator as the Changchun main plant to simulate the shipping process. Click on the "Generator" label and set the arrival mode to "Arrival Schedule". Set "Quantity", the total transport volume Q, to 288 vehicles.

(2) Vehicle Preparation and Loading

Set the synthesizer to simulate the vehicle preparation and loading process, ensuring vehicle capacity is met. Click the "Processing Time" label in the "Synthesis Mode" and set it to "Packaging". Then set "Target Quantity" to 6, 9, and 6 respectively, representing the loading capacity of each vehicle for DMU1, DMU2, and DMU3 schemes [10].

(3) Loading Process

Set the generator to simulate the loading process during the 8 km shuttle transport. Click the "Processor" label, and set "Processing Time" to 45, 68, and 45 minutes respectively for DMU1, DMU2, and DMU3 based on the loading times of the vehicles in each scheme.

(4) Transport Process

Set the processor to simulate the transport process of the car transporter. Click the "Processor" label, and set "Processing Time" to 24, 32, and 64 minutes respectively for DMU1, DMU2, and DMU3 based on the round-trip driving times of the vehicles in each scheme.

(5) Unloading Process

Set the decomposer to simulate the unloading process. Click the "Processing Time" label, and set "Processing Time" to 15, 23, and 15 minutes respectively for DMU1, DMU2, and DMU3 based on the unloading times of the vehicles in each scheme.

4.4. Simulation Experiment Results and Analysis

Due to the different loading capacities, driving speeds, loading times, and unloading times of the vehicles chosen under the three schemes, the round-trip driving time and simulation running time during the shuttle transport process also differ. The simulation results were organized, and the model running time was converted into equivalent operating hours as shown in Table 4.

Table 4. Summary of Simulation Model Running Times

Scheme	Running Time (min)	Equivalent Operating Hours (h)
DMU1	2207.60	36.79
DMU2	2243.70	37.40
DMU3	3140.60	52.34

Substituting the above formulas, the transport costs for the three schemes were obtained as shown in Table 5.

Table 5. Solution Results for Shuttle Transport Cost Model of an Automobile Company

Parameter Scheme	DUM1	DUM2	DUM3
Hourly Volume	7.83	7.70	5.50
Hourly Volume after Loading	1.30	0.86	0.92
Total Volume after Loading	48	32	48
Number of Vehicles	36.79	37.395	52.34
Rounded Number of Vehicles	37	38	53
Unit Price (100,000 yuan)	120	150	100
Total Price (100,000 yuan)	4440	5700	5300

In summary, through the simulation calculations of the 8 km shuttle transport process for the three car transporters and the comparative analysis of the simulation results of the three transport schemes, it can be seen that the transport cost of the DMU1 scheme is the lowest. Based on the goal of achieving the lowest total transport cost and shortest total time in the shuttle transport process, the optimal transport scheme selected is DMU1, which uses L3-level automated heavy trucks with double-deck trailers. A total of 37 vehicles are required to complete the target shuttle transport [4].

5. Conclusion

This paper focuses on the 8-kilometer shuttle transport of an automobile company in the Changchun area with the aim of solving practical problems. For the issue of selecting and allocating resources for 8-kilometer car transporters, an optimization goal of minimizing vehicle purchase costs was proposed. FlexSim software was used to simulate the shuttle transport process for three car transporter schemes, and the operation results were mathematically analyzed. It was found that deploying 37 L3-level automated heavy trucks with double-deck trailers to complete the shuttle transport can achieve the optimization goal of minimizing vehicle purchase costs. This further optimizes the car transporter selection and resource allocation for the automobile company. The automobile company can adopt the approach presented in this paper and select the appropriate vehicle models and corresponding resource allocation schemes based on its own situation.

Authors' Contributions

Wang Lianfan and Li Yanyi: Writing the First Draft, Data Investigation and Sorting, Software Simulation, Mathematical Analysis, and Paper Revision. Both authors contributed equally to the article.

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