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Design of a Bicycle Sharing Inventory Scheduling System Based on Big Data Prediction

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Abstract: In the context of the rapid development of the sharing economy, shared bikes as its representative products rise rapidly. Among many problems, the problem of bicycle stock scheduling is the most severe, which will directly bring great troubles to People's Daily life. This paper compares and understands various demand forecasting methods by minimizing the scheduling cost as the objective function. By using BP neural network, this paper provides reference for the following demand data of the shared bike stock scheduling system, and builds the shared bike stock scheduling system to solve this problem.

Keywords: Bike sharing, Scheduling, Demand forecasting, MATLAB, BP neural network.

1. Introduction

With the popularization of green environmental awareness and the involvement of capital, the coverage of bike sharing has expanded unprecedentedly, gradually highlighting many problems, such as "it is difficult to find a bike," "it is difficult to return a bike," and even disorderly parking, causing damage to vehicles [1]. Therefore, if shared bicycles are parked in disorder or vehicles are not dispatched in time, resulting in excessive accumulation of vehicles in some bike-sharing rental points, this will not only harm the production and life of residents around but also cause problems to users' sense of the experience of using shared bicycles, and will also bring considerable challenges to the ecological environment and urban management. Today, sharing bicycles is so popular that an efficient scheduling scheme plays a critical role in saving time and improving enterprise scheduling efficiency. How to forecast the demand for shared bicycles at the bike-sharing rental point through Internet technology and complete the scheduling quickly and reasonably has become a more critical problem.

This paper studies eight bike-sharing rental sites near the university and uses BP neural network to predict the demand for each site. Through field investigation, the study found that in the evening, when students return to school, there are often too many bicycles at the bike-sharing rental point at the school gate, which leads to a severe shortage of vehicles in other bike-sharing rental points near the school, such as subway stations and hospitals, bringing great inconvenience to users who need to use bicycles the next day. Therefore, it is necessary to study how to make the most scientific and reasonable vehicle scheduling in each shared bicycle rental point to meet the everyday use of each shared bicycle rental point the next day and minimize the scheduling cost of bicycle-sharing enterprises.

2. BP Neural Network Prediction

2.1. BP neural network demand forecasting process

As a neural network with multi-level architecture, BP neural network is generally composed of three or more layers, namely the hidden layer, input layer, and output layer, and the hidden layer can be one or more levels. Each layer of the neuron can not be connected to the same layer, nor can cross-layer connections be implemented. The neighboring neurons are interconnected. The demand forecasting process of the BP neural network can be roughly divided into input and output layer design, data source, sample processing, parameter selection, and setting. In the structure of the BP neural network, the input layer only has the function of inputting data and does not participate in any process. The number of nodes depends on the number of attributes of the sample. The basic process of the BP neural network is unified, as shown in Figure 1:

Formula (1) is used to normalize data into numbers between (0,1); Formula (2) normalizes the input data into a number between (- 1,1). In the above formula, x means the input data; $x_{min}x_{min}$ refers to the minimum value in this group of data; x_{max} refers to the maximum value in this data group; X represents the data result obtained after the normalization formula processes the data.

$$X = \frac{x - x_{min}}{x_{max} - x_{min}} \quad (1)$$

$$X = \frac{2(x - x_{min})}{x_{max} - x_{min}} - 1 \quad (2)$$

If the demand is nonlinear, the nonlinear sigmoid function is used as the activation function of the neural network, and its expression is shown in Formula (3),

$$f(x) = \frac{1}{1 + e^{-x}} \quad (3)$$

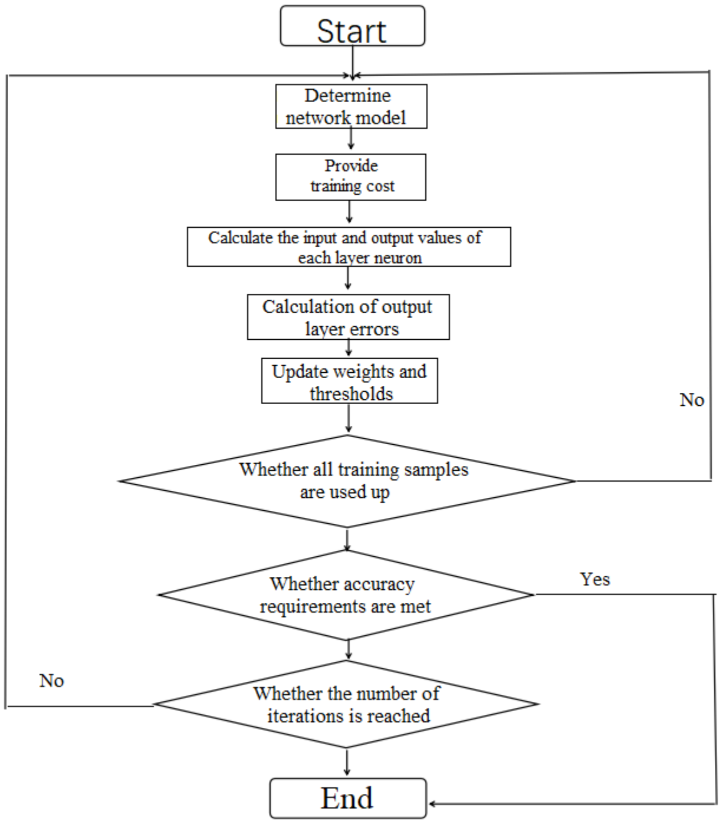

Figure 1. Basic Process of BP Neural Network

Since the number of shared bicycles at the parking point cannot be known in real-time, the BP neural network program is programmed through MATLAB. Among the eight bike-sharing rental points studied in this paper, the number of people in the bike-sharing rental points near the hospital is large, which reflects the rental demand of people for vehicles in real life. Therefore, the predicted number of hospital car rentals is compared with the actual number of car rentals, and the results are shown in Figure 2.

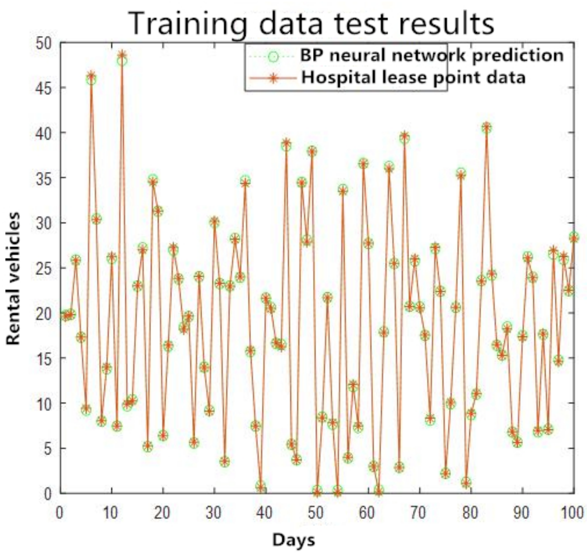

Figure 2. Forecast Results of Hospital Car Rental

It can be seen from Figure 2 that the overall trend and value of the car borrowing volume predicted by the BP neural network are very close to the absolute value of the hospital-shared bicycle rental point, and the relative prediction error is also small. Therefore, the demand for eight shared bicycle rental points near the school can be predicted through BP neural network to obtain the demand for each bike rental point.

3. Determine Data Structure

This paper adopts the scheduling model without a time window [2]. In order to scientifically and reasonably consider the number of shared bicycles, it records the vehicle data of eight shared bicycle rental points that come to the school and the surrounding area at a specific time point for five consecutive days. It calculates the actual number of vehicles that need to be transferred for the shared rental bicycle rental. As shown in Table 1:

The BP neural network is used to predict the actual number of vehicles required for the sharing of leased bicycles at the eight shared bicycle rental points scientifically and reasonably. The demand is the difference between the predicted number of borrowed and returned vehicles. The results are shown in Table 2. By calculating the difference between the data in Table 1 and Table 2, the number of vehicles dispatched at each shared bicycle rental point can be calculated. As shown in Table 3:

Where a positive value means that vehicles need to be transferred from this station to other shared bicycle rental points, and a negative value means that this station needs to transfer vehicles from other stations to this station. It was evident that, except for the bike rental points shared by the east gate and the west gate of the university, the other five stations are in a state of lack of vehicles. Therefore, it is necessary to complete the vehicle scheduling at these eight points before the rush hour of the next day. Against this background, the optimal scheduling path and scheduling quantity are established, which makes the Research of this paper have practical significance.

Table 1. Number of Bicycles in Shared Bicycle Rental Points

Number of vehicles	The East Gate of the University	West Gate of the University	High speed railway station	Metro Exit 1	Metro Exit 2	Hospital	Business-street	Business-street
Monday	193	168	17	11	16	21	69	56
Tuesday	186	192	14	9	18	24	65	54
Wednesday	218	171	19	14	20	18	73	50
Thursday	198	179	13	13	13	15	59	52
Frid	206	183	20	2	11	28	29	54
Average value	200.2	178.6	16.6	9.8	15.6	21.2	59	53.2

Table 2. Single Vehicle Demand of Shared Bicycle Rental Points

Bike sharing rental point	The East Gate of the University	West Gate of the University	High speed railway station	Metro Exit 1	Metro Exit 2	Hospital	Business-street	Business-street
Requirement	128	79	45	45	30	41	105	72

Table 3. Traffic volume of single car in the shared single car rental point

Bike sharing rental point	The East Gate of the University	West Gate of the University	High speed railway station	Metro Exit 1	Metro Exit 2	Hospital	Business-street	Business-street
Traffic volume to be adjusted	62	100	-28	-35	-14	-20	-46	-19

4. Methodology of Sharing Single Vehicle Stock Scheduling

4.1. Problem description

In order to solve the problem of shared bicycle scheduling, researchers focus on the demand of the scheduling system and the scheduling path from the total scheduling distance and carry out optimization analysis [3-4]. In order to minimize the final inventory of the shared single-vehicle node, the static operation mode of single-vehicle scheduling is considered in the research process [5-6]. Considering the nature of shared bicycles, researchers use the regional dispatching mode to optimize many modules in the overall dispatching process [7-8].

The report obtained after sorting out and summarizing shows that the east gate of the university and the west gate of the university will have 62 more bicycles and 100 more shared bikes each day between 22:00 and 6:00 the next day. In contrast, the high-speed railway station, subway entrance 1, subway entrance 2, hospital, commercial street, residential area, and other shared bike rental sites will have 28, 35, 14, 20, 46 19 shared bicycles. The eight bike-sharing rental points are the east gate of the university, the west gate of the university, the high-speed railway station, the commercial street, the subway exit 1, the subway exit 2, the hospital, and the residential area. For the convenience of the following example calculation and analysis, the eight bike-sharing rental points are temporarily marked with numerical symbols, as shown in Table 4:

Because the sharing cycle scheduling process requires the participation of manual driving. That is, it requires inputting human and material resources and other costs. In order to better optimize the solution, analyze the cost in the process of shared bicycle dispatching, and now convert it into data and calculate the cost per kilometer. As shown in Table 5 below:

Table 4. Identification Table

Bike sharing rental point	The East Gate of the University	West Gate of the University	High speed railway station	Metro Exit 1	Metro Exit 2	Hospital	Business-street	Business-street
Grade	A1	A2	B1	B2	B3	B4	B5	B6

Table 5. Cost Table

Cost (yuan)	B1	B2	B3	B4	B5	B6
A1	2	3	1	4	2	2
A2	1	3	2	3	2	2

4.2. Model establishment

The problem studied and solved in this paper is a relatively complex transportation system planning problem. Therefore, a mathematical model of transportation planning based on the above two transportation modes is proposed, as well as the specific scheduling of shared bicycles from the assigned location to the distribution location under this model. Therefore, large-scale linear planning problems need to follow two starting rules:

Rule 1: The transportation cost is the minimum.

Rule 2: The number of bicycles in each rental site can reach the next day's usage.

According to the above two starting rules, the objective function can be obtained as shown in Equations 4-8 below.

$$\min f = \sum_{i=1}^{m} \sum_{j=1}^{n} ak_{ij} x_{ij} \tag{4}$$

It is assumed that several transport trucks participate in the dispatching, and the carrying capacity of the trucks is sufficient to cope with the daily shared single-vehicle dispatching volume. The number of bicycles transferred out must be able to meet the demand of the allocated bike-sharing point and the number of bicycles in the allocated bike-sharing point to ensure regular use the next day.

$$s.t.\begin{cases} \sum_{j=1}^{n} x_{ij} = C_i \\ \sum_{i=1}^{m} x_{ij} = E_j \\ x_{ij} \geq 0 \end{cases} \tag{5}$$

Among them, a is the cost of single vehicle transportation per kilometer, x_{ij} is the single vehicle dispatching volume required by each shared bicycle rental point, C_i is the number of vehicles that need to be transferred from the East Gate of the University and the West Gate of the University, E_i is the vehicles that need to be transferred from the shared bicycle rental point except the East Gate of the University and the West Gate of the University, and k_{ij} is the dispatching distance required from the East (West) Gate of the University to other shared bicycle rental points.

After using the Linprog function in MATLAB software to analyze and process the data, it can be found directly in the process of data analysis that 2, 14, and 46 shared rental bicycles were successively dispatched from the east gate of the university to the first subway entrance, the second subway entrance, and the hospital; At Ximen Station of the University, about 28, 33, 20 and 19 shared bicycles can be transferred to the high-speed railway station, Metro Entrance 1, commercial street and residential area respectively. Based on this, the dispatching design system calculates that the lowest dispatching cost can be obtained using this transportation dispatching method, which is about 337 yuan.

5. Results and Optimization Discussion

As we all know, it is inevitable that a shared bike will bump and be damaged during use. It is assumed that the vehicles in several shared bicycle rental points near the school cannot be used due to damage. If the vehicles at the east gate and the west gate of the university cannot be put into everyday use due to damage, there are 16 and 24 vehicles, respectively. In order to ensure standard work and to commute the following day, the number of bicycles cannot be reduced. After considering the planning, it is planned to ensure that the number of shared bicycles in the residential area remains unchanged. The number of bicycles for the high-speed railway station, commercial street, and the hospital shall be reduced by 10, 10, and 20, respectively, at most, and the number of bicycles for dispatching to subway exit I and subway exit II shall not be less than 30 and 10, respectively.

In this case, establish the objective function of the model, as shown in Formula (6):

$$\min f = 2x_{11} + 3x_{12} + 1x_{13} + 4x_{14} + 2x_{15} + 3x_{16} + 1x_{21} + 3x_{22} + 2x_{23} + 3x_{24} + 2x_{25} + 2x_{26} \tag{6}$$

According to the overall planning proposed above, the following linear constraints can be obtained:

$$s.t.\begin{cases} x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} = 46 \\ x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} = 76 \\ 18 \leq x_{11} + x_{21} \leq 28 \\ 30 \leq x_{12} + x_{22} \leq 35 \\ 10 \leq x_{13} + x_{23} \leq 14 \\ 10 \leq x_{14} + x_{24} \leq 20 \\ 26 \leq x_{15} + x_{25} \leq 46 \\ x_{16} + x_{26} = 19 \end{cases} \tag{7}$$

The optimal solution of linear programming is calculated by using the Linprog function in MATLAB, and the dispatching cost minimization table is shown in Table 6 below:

Table 6. Scheduling Cost Minimization in the Case of Vehicle Damage

Dispatch volume	B1	B2	B3	B4	B5	B6
A1	0	6	14	0	26	0
A2	23	24	0	10	0	19

After using the Linprog function in MATLAB software to analyze and process the data, it can be found directly in the process of data analysis that 6, 14, and 26 shared rental bicycles were successively dispatched from the east gate of the university to the first subway entrance, the second subway entrance, and the hospital; At the Ximen Station of the University, about 23, 24, 10 and 19 shared bicycles can be transferred to the high-speed railway station, Metro Exit 1, Business Street and residential areas respectively. According to this, the optimal dispatching design system calculates that the lowest dispatching cost that can be obtained using this transportation dispatching method is 209 yuan.

However, there are often some exceptional circumstances, such as the expansion of the school campus, the increase of students, and the demand of teachers and students for bike sharing. Thirty and 40 shared bikes were allocated to the east gate and the west gate of the university, respectively. At the same time, due to the establishment of a large factory near the school, the number of factory staff has increased, and the number of residents in the residential area has increased dramatically. The demand for shared bicycles has also increased, and 20 bicycles have been transferred to the residential area. The traffic volume of the high-speed railway station, subway entrance 1, subway entrance 2, commercial street, and the hospital will increase by 20, 15, 30, 5, and 24 at most, respectively.

In this case, establish the objective function of the model, as shown in Formula (8):

$$\min f = 2x_{11} + 3x_{12} + 1x_{13} + 4x_{14} + 2x_{15} + 3x_{16} + 1x_{21} + 3x_{22} + 2x_{23} + 3x_{24} + 2x_{25} + 2x_{26} \quad (8)$$

According to the overall planning proposed above, the following linear constraints can be obtained:

$$s.t.\begin{cases} x_{11} + x_{12} + x_{13} + x_{14} + x_{15} + x_{16} = 92 \\ x_{21} + x_{22} + x_{23} + x_{24} + x_{25} + x_{26} = 140 \\ 28 \le x_{11} + x_{21} \le 48 \\ 35 \le x_{12} + x_{22} \le 50 \\ 14 \le x_{13} + x_{23} \le 44 \\ 20 \le x_{14} + x_{24} \le 25 \\ 46 \le x_{15} + x_{25} \le 70 \\ x_{16} + x_{26} = 39 \end{cases} \quad (9)$$

The optimal solution of linear programming is calculated by using the Linprog function in MATLAB, and the dispatching cost minimization table is shown in Table 7 below:

Table 7. Dispatching Cost Minimization in the Case of Vehicle Damage

Dispatch volume	B1	B2	B3	B4	B5	B6
A1	0	2	44	0	46	0
A2	48	33	0	20	0	39

After using the Linprog function in MATLAB software to analyze and process the data, it can be found directly in the process of data analysis that 2, 44, and 46 shared rental bicycles were successively dispatched from the east gate of the university to the first subway entrance, the second subway entrance, and the hospital; About 48, 33, 20 and 39 bike sharing vehicles are transferred to the commercial streets and residential areas respectively. According to this, the optimal dispatching design system calculates that the lowest dispatching cost that can be obtained with this transportation dispatching method is 427 yuan.

6. Conclusion

As a new mode of transportation under the rapid development of sharing economy since the 21st century, bike sharing has dramatically contributed to solving the problem of short-distance transportation. Consumers widely favor it because of its low-carbon, environment-friendly, convenient, and fast characteristics. The Research starts from reality and takes the small life circle near the school as an example to design shared bicycle scheduling. The BP neural network algorithm is used to predict the rental volume of shared single-car rental points in advance. The mathematical model based on linear programming minimizes the scheduling cost as the objective function. The Linprog function in MATLAB processes the data and discusses the scenarios according to the actual situation. The optimal scheduling method under different scenarios is obtained, which significantly alleviates the imbalance between the supply and demand of single cars at the stations near the school and facilitates the travel of the masses. It can also reduce the operating costs of relevant single-vehicle operating enterprises. For the development of bike-sharing enterprises, user satisfaction will be beneficial without harm, which has solid practical significance and social benefits.

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