THE MAIN CONTENTS

01  INRODUCTION

02  MATHEMATICAL MODEL

03  SOLUTION ALGORITHM

04  CASE STUDY

05  CONCLUSION
Introduction
01 BACKGROUND

Convenient

Environment friendly

Healthy
About three decades ago, China was known as the “Bicycle Kingdom”
commuter travel

before 6:00 6:00-8:00 8:00-11:00 11:00-13:00 13:00-17:00 17:00-19:00 after 19:00
2 Mathematical Model
VRP model

- The bike-sharing scheduling problem can be regarded as a conventional vehicle routing problem (VRP).
- Bicycles are equal to the goods
- Maintenance vehicle are bounded to send all the bicycles to some specific areas
- The objective of the bicycle dispatching is to minimize the total cost.
- The total operating cost in this model is composed of two parts: fixed costs, and the variable transportation costs.
VRP model for bike-sharing scheduling problem

\[
\begin{align*}
\text{Min} & \quad a \sum_{k=1}^{K} \sum_{j=1}^{n} X_{0,jk} + c \sum_{k=1}^{K} \sum_{j=0}^{n} \sum_{i=0}^{n} d_{ij} X_{ijk} \\
& \sum_{k=1}^{K} \sum_{i=0}^{n} X_{ijk} = 1 \quad j = 1, 2, \ldots, n \quad (2) \\
& \sum_{j=1}^{n} \sum_{i=1}^{n} q_{ij} X_{ijk} \leq Q \quad k = 1, 2, \ldots, K \quad (3) \\
& \sum_{k=1}^{K} \sum_{i=0}^{n} X_{i0k} \leq K \quad k = 1, 2, \ldots, K \quad (4) \\
& \sum_{i=0}^{n} X_{i0k} \leq 1 \quad k = 1, 2, \ldots, K \quad (5) \\
& \sum_{i=0}^{n} X_{ijk} = \sum_{i=0}^{n} X_{jik} \quad j = 1, 2, \ldots, n \quad k = 1, 2, \ldots, K \quad (6) \\
& \sum_{i \in S} \sum_{j \in S} X_{ijk} \leq |S| - 1 \quad \forall S \subseteq I \quad k = 1, 2, \ldots, K \quad (7) \\
& X_{ijk} = \{0, 1\} \quad (8)
\end{align*}
\]
3

Solution
Algorithm
PSO (The Particle Swarm Optimization)

- The PSO algorithm is an evolutionary algorithm, which originates from research into bird flock preying behavior. The PSO algorithm is similar to a genetic algorithm, both of which are based on iteration.
- During each iteration, each particle refreshes itself by following the two types of best solutions:
  - (i) the optimal solution for each individual
  - (ii) the optimal solutions of the population.
Two spatial vectors are designed to represent the solution: $k$ denotes the number of the vehicle for each path, while $r$ denotes the precedence order of vehicle arrival at the consumers.

<table>
<thead>
<tr>
<th>No</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>$X_k$</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>$X_r$</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
</tbody>
</table>

First vehicle: 0→5→1→8→0,
Second vehicle: 0→4→2→3→0
Third vehicle: 0→6→7→0
PSO (The Particle Swarm Optimization)

(1) The improvement of inertia weight.

\[ W = w_{\text{max}} - (w_{\text{max}} - w_{\text{min}}) \cos \left( \left( \frac{t}{T} - 1 \right) \pi \right), \]

(2) The improvement of learning factors

\[ c_1 = c_{1\text{max}} - (c_{1\text{max}} - c_{1\text{min}}) \cos \left( \left( \frac{t}{T} \right) - 1 \right) \pi, \]

\[ c_1 = c_2. \]
Case study

- Data sauces:
  No R101 testing data is from VRPTW test bank designed by Solomon in 1983, which includes 25 pairs of coordinates, time windows, service time and demands.

<table>
<thead>
<tr>
<th>Number</th>
<th>Coordinate</th>
<th>Demand</th>
<th>Service time</th>
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<tbody>
<tr>
<td>DC</td>
<td>(35,35)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>1</td>
<td>(41,49)</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>(35,17)</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>(55,45)</td>
<td>13</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
<td>(55,20)</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>5</td>
<td>(15,30)</td>
<td>26</td>
<td>10</td>
</tr>
<tr>
<td>6</td>
<td>(25,30)</td>
<td>3</td>
<td>10</td>
</tr>
<tr>
<td>7</td>
<td>(20,50)</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>8</td>
<td>(10,43)</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>9</td>
<td>(55,60)</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>10</td>
<td>(30,60)</td>
<td>16</td>
<td>10</td>
</tr>
<tr>
<td>11</td>
<td>(20,65)</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>12</td>
<td>(50,35)</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
<td>13</td>
<td>(30,25)</td>
<td>23</td>
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</tr>
<tr>
<td>14</td>
<td>(15,10)</td>
<td>20</td>
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<tr>
<td>15</td>
<td>(30,5)</td>
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<td>(10,20)</td>
<td>19</td>
<td>10</td>
</tr>
<tr>
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<td>(5,30)</td>
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<td>(20,40)</td>
<td>12</td>
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<td>(15,60)</td>
<td>17</td>
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</tr>
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<td>(45,65)</td>
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<td>(45,10)</td>
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<td>(55,5)</td>
<td>29</td>
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</tr>
<tr>
<td>24</td>
<td>(65,35)</td>
<td>3</td>
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</tr>
<tr>
<td>25</td>
<td>(65,20)</td>
<td>6</td>
<td>10</td>
</tr>
</tbody>
</table>
After the 160th iteration, the algorithm converges and the optimal solution is 17020.

A total five maintenance trucks are assigned to serve all the spots,

<table>
<thead>
<tr>
<th>Number</th>
<th>Path</th>
<th>Load factor (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0→2→18→14→15→1→6→17→3→1</td>
<td>94</td>
</tr>
<tr>
<td></td>
<td>2→0</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>0→4→24→25→8→20→11→0</td>
<td>58</td>
</tr>
<tr>
<td>3</td>
<td>0→7→5→16→22→23→0</td>
<td>97</td>
</tr>
<tr>
<td>4</td>
<td>0→13→21→9→0</td>
<td>50</td>
</tr>
<tr>
<td>5</td>
<td>0→10→19→0</td>
<td>33</td>
</tr>
</tbody>
</table>
Conclusion
Considering the problems happening in the rapid development of the bike-sharing, the VRP model for bike-sharing inventory rebalancing and vehicle routing is established.

An improved PSO algorithm is designed by changing the inertia weight and learning factors.

A case study has been analyzed and the validity and practicability of the mathematical model and algorithm have been verified.
In the initial stage of the development of the bike-sharing system, manpower scheduling is the main solution to the uneven distribution of bikes.

According to the calculation results, the load factor of one maintenance truck is lower than 50%. That is to say, there are some improvements and modification in the algorithm.
Thanks for your attention!

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