**MOTIVATION**
- Rapid growth of Bicycle Sharing Systems (BSSs) all around the world
- BSSs have many benefits such as reducing the congestion and pollution
- Challenges faced by BSSs include system imbalance, theft/vandalism and policy

**SYSTEM IMBALANCE PROBLEM**
- Imbalanced state of the system:
  - This causes dissatisfaction among the users and might also lead to a loss of users and revenue
  - It is crucial to the success of the system
  - Incentivized Redistribution: Incentives provided to the users for self-repositioning
  - Static Repositioning: Bicycles are repositioned when the system is 'inactive'
  - Hybrid Repositioning: A mixed strategy using both static and dynamic repositioning

**OBJECTIVES**
- Develop optimization models for the static repositioning of bicycles in a BSS to:
  - Ensure the minimum availability of bicycles and empty docks at the stations
  - Minimize the cost of the repositioning operation

**STATIC REPOSITIONING**
- The operation cost has 3 components: Time cost, Fuel cost and Labor cost
  - The static repositioning operation takes place when the system is ‘inactive’ – i.e. when very few users are using the system
  - Characteristics:
    - An inexpensive way of doing the repositioning
    - It can handle systems which are not too dynamic
    - Challenges:
      - It cannot be used to quickly respond to unusual changes in the demand
      - It cannot be used in very active systems

**META-HEURISTIC ALGORITHM FOR STATIC REPOSITIONING PROBLEM IN CYCLE SHARING SYSTEMS**
- The heuristic algorithm was applied to the Velo Antwerpen network
- The demand pattern on the weekends is found to be suitable for Static Repositioning

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**REAL WORLD NETWORK APPLICATION AND RESULTS**
- Table 1 Comparison of MILP with Heuristic (Standard Deviations in parentheses)

<table>
<thead>
<tr>
<th>Size</th>
<th>Deadline (min)</th>
<th>ResBSSM Cost (min)</th>
<th>MILP with Heuristic Cost (min)</th>
<th>Computational Time (s)</th>
<th>Cost savings (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>35</td>
<td>84.25</td>
<td>87.4 (0.34)</td>
<td>71.80 (1.91)</td>
<td>4444</td>
</tr>
<tr>
<td>12</td>
<td>45</td>
<td>77.75</td>
<td>78.2 (0.45)</td>
<td>68.5 (1.42)</td>
<td>1285</td>
</tr>
<tr>
<td>13</td>
<td>40</td>
<td>80</td>
<td>80.3 (0.5)</td>
<td>83.95 (1.18)</td>
<td>26478</td>
</tr>
<tr>
<td>13</td>
<td>50</td>
<td>73</td>
<td>74.8 (0.45)</td>
<td>67.9 (1.82)</td>
<td>4803</td>
</tr>
<tr>
<td>14</td>
<td>50</td>
<td>77</td>
<td>78.4 (0.89)</td>
<td>72.7 (1.02)</td>
<td>36435</td>
</tr>
</tbody>
</table>

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**CONCLUSIONS**
- The proposed heuristic algorithm is a good way for the static repositioning of bicycles in a BSS with a low activity level
- The comparison of the heuristic and the MILP shows a close gap to the optimal results
- The results show that considerable cost savings can be obtained by using the proposed heuristic algorithm instead of the traditional repositioning methods

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**MIXED INTEGER LINEAR PROGRAMMING MODEL FOR STATIC REPOSITIONING**

\[
\begin{align*}
\text{min} & \quad \sum_{i,j,k} t_{ij} x_{ij}^k \\
\text{subject to} & \quad \sum_{j \in N} x_{ij}^k = 1, \forall i \in N, \forall k \in V \\
& \quad \sum_{i \in N} x_{ij}^k = 1, \forall i \in N, \forall j \in V \\
& \quad \sum_{k \in V} x_{ij}^k v_k \in N, \forall i \in N, \forall j \in V \\
& \quad \sum_{k \in V} x_{ij}^k v_k \in N, \forall i \in N, \forall j \in V \\
& \quad u_{ij}^k \geq u_{ij}^k + s_{ij} (x_{ij}^k + x_{ij}^l) - 1, \forall i, j \in N, \forall k \in V \\
& \quad Q_k - (Q_k - 1) \cdot M \leq u_{ij}^k \leq Q_k - (Q_k - 1) \cdot M, \forall i, j \in N, \forall k \in V \\
& \quad t_{ij}^k \geq t_{ij}^k + s_{ij} (x_{ij}^k + x_{ij}^l - 1), \forall i, j \in N, \forall k \in V \\
& \quad t_{ij}^k \geq t_{ij}^k + s_{ij} (x_{ij}^k + x_{ij}^l - 1), \forall i, j \in N, \forall k \in V \\
& \quad \sum_{i \in N} t_{ij}^k + t_{ij}^k \leq D, \forall i, j, k \in N, k \in V \\
& \quad \sum_{k \in V} x_{ij}^k \leq 1, \forall i \in N, \forall j \in V \\
& \quad u_{ij}^k, s_{ij}, t_{ij}^k, v_k \in \mathbb{R} \\
\end{align*}
\]

**CONCLUSIONS**

- The proposed heuristic algorithm is a good way for the static repositioning of bicycles in a BSS with a low activity level
- The comparison of the heuristic and the MILP shows a close gap to the optimal results
- The results show that considerable cost savings can be obtained by using the proposed heuristic algorithm instead of the traditional repositioning methods