## Contents

1 Introduction .................................................................................. 1

Part I Problem Description

2 Bike Sharing in the Context of Urban Mobility ......................... 7
   2.1 Mobility, Urban Transportation Challenges, and Trends ...... 8
      2.1.1 Mobility Needs and Behavior .................................. 9
      2.1.2 Basics of Urban Transportation .............................. 10
      2.1.3 Urban Transportation Challenges ............................ 13
      2.1.4 Trends in Urban Mobility and Transportation .......... 14
    2.2 Bike Sharing Systems as a Concept of Shared Mobility ...... 15
       2.2.1 Usage-Oriented Motives for Shared Mobility .......... 15
       2.2.2 Business Models of Shared Mobility Systems .......... 18
       2.2.3 Information Systems Support of Bike Sharing Systems .. 21
       2.2.4 General Guidelines on the Planning, Implementation,
            and Operation of BSS ........................................... 25

3 Service Network Design as a Logistical Challenge in the Reliable
   Provision of Service in Bike Sharing Systems .......................... 31
   3.1 Classification of Logistical Planning Levels for SMS ............. 32
   3.2 Service Network Design for Tactical Planning of BSS ........... 35
      3.2.1 General Concept of Service Network Design in Freight
            Transportation .................................................. 35
      3.2.2 Special Requirements of Tactical Planning in BSS ........ 37
   3.3 Appreciation of Literature Related to Logistical Planning Levels
      for SMS ................................................................. 40
      3.3.1 Operational and Strategic Planning .......................... 40
      3.3.2 Tactical Planning .............................................. 43
   3.4 Intelligent Data Analysis and Optimization for Service Network
      Design of Bike Sharing Systems ..................................... 45
Part II  Intelligent Data Analysis

4  Determination of Typical Bike Flows ............................................. 51
   4.1 An Information Model for Generation of Typical Bike Flows .... 52
      4.1.1 Combining Intelligent Data Analysis and Transportation
            Planning ................................................................. 52
      4.1.2 Formalization of the Information Model ....................... 55
   4.2 Intelligent Data Analysis for Parameterization of the Information
       Model ........................................................................ 60
      4.2.1 Preprocessing to Create the Target Data Set ............. 64
      4.2.2 Data Exploration to Understand Bike Imbalances
            and Determine the Temporal Scope
            of Tactical Planning ............................................... 66
      4.2.3 Determine Trip Purposes by Cluster Analysis .......... 67

5  Case Study: Generation of Typical Bike Flows
   for Citybike Wien ................................................................. 81
   5.1 Preprocessing to Create the Target Data Set ................. 82
   5.2 Spatial and Temporal Exploration of Trips ..................... 84
      5.2.1 Spatial Exploration to Understand Trip Generation
            and Attraction ....................................................... 84
      5.2.2 Temporal Exploration to Determine the Tactical Planning
            Scope ................................................................. 87
      5.2.3 Spatiotemporal Exploration to Show the Flaw
            of Averages ......................................................... 92
   5.3 Determination of Trip Purposes ................................. 94
      5.3.1 Temporal Distribution of Trips .............................. 95
      5.3.2 Spatial Distribution of Trips ............................... 99
   5.4 Generation and Validation of Typical Bike Flows ........ 101
   5.5 Generating Artificial Instances of Bike Sharing Systems ... 104

Part III  Optimization

6  Service Network Design of Bike Sharing Systems ................. 113
   6.1 Related Approaches of Dynamic Service Network Design ... 113
   6.2 Mixed-integer Programming Formulation for SND of BSS .... 117
   6.3 A Hybrid Metaheuristic to Solve the Service Network Design
        Model ........................................................................ 122
      6.3.1 Selecting a Suitable Hybrid Metaheuristic Concept .... 122
      6.3.2 MIP-Based Large Neighborhood Search for Dynamic
            SND of BSS .......................................................... 125
      6.3.3 Obtaining a Starting Solution by LP Relaxation ........ 128
<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>6.4 Investigating the Performance of Solution Methods Using Artificial Instances</td>
<td>129</td>
</tr>
<tr>
<td>6.4.1 Experimental Setup</td>
<td>129</td>
</tr>
<tr>
<td>6.4.2 Performance of Solution Methods</td>
<td>131</td>
</tr>
<tr>
<td>6.4.3 Effect of Neighborhood Operators</td>
<td>132</td>
</tr>
<tr>
<td>7 Case Study: Service Network Design of Citybike Wien</td>
<td>137</td>
</tr>
<tr>
<td>7.1 Experimental Setup</td>
<td>137</td>
</tr>
<tr>
<td>7.2 Performance of Solution Methods and Neighborhood Operators</td>
<td>138</td>
</tr>
<tr>
<td>7.2.1 Performance of Solution Methods</td>
<td>138</td>
</tr>
<tr>
<td>7.2.2 Effect of Neighborhood Operators</td>
<td>140</td>
</tr>
<tr>
<td>7.3 Service Network Design for Different Scenarios</td>
<td>141</td>
</tr>
<tr>
<td>7.3.1 The Current System Configuration with Low Demand</td>
<td>142</td>
</tr>
<tr>
<td>7.3.2 Comparison of Demand Scenarios</td>
<td>147</td>
</tr>
<tr>
<td>7.4 The Benefit and Usefulness of Service Network Design</td>
<td>153</td>
</tr>
<tr>
<td>Part IV Conclusion</td>
<td></td>
</tr>
<tr>
<td>8 Conclusions and Outlook</td>
<td>157</td>
</tr>
<tr>
<td>Bibliography</td>
<td>161</td>
</tr>
</tbody>
</table>
Service Network Design of Bike Sharing Systems
Analysis and Optimization
Vogel, P.
2016, XII, 167 p. 50 illus., 20 illus. in color., Hardcover
ISBN: 978-3-319-27734-9