# Contents

1. Introduction 1
   1.1 Overview of Thesis 5

2. Network Design 10
   2.1 Graph Models 11
   2.2 Basic Network Models 12
      2.2.1 Spanning Tree Models 13
      2.2.2 Shortest Path Model 13
      2.2.3 Maximum Flow Model 15
   2.3 Network Design Problems 15
      2.3.1 Spanning Tree Problem 16
         2.3.1.1 Minimum Spanning Tree Problem 16
         2.3.1.2 DCMST 18
      2.3.2 Shortest Path Problem 20
      2.3.3 Traveling Salesman Problem 21
      2.3.4 Considered Problems 23
      2.3.5 Backbone Network Design Problem 24

3. Methodologies 29
   3.1 Exact Algorithms 30
      3.1.1 Linear Programming 31
         3.1.1.1 Branch & Bound 33
      3.1.2 Dynamic Programming 33
   3.2 Heuristics 35
      3.2.1 Kruskal Algorithm 35
      3.2.2 Prim Algorithm 37
      3.2.3 Breadth First Search Algorithm 38
      3.2.4 Depth First Search Algorithm 40
      3.2.5 Dijkstra Algorithm 41
      3.2.6 Metaheuristics 43
         3.2.6.1 Genetic Algorithm 44
         3.2.6.2 Simulated Annealing 45
         3.2.6.3 Local Search 46
         3.2.6.4 Best First Search 49
         3.2.6.5 Tabu Search 49
         3.2.6.6 Ant Colony Optimization 50
         3.2.6.7 GRASP 53
         3.2.6.8 Artificial Bee Colony Algorithm 54
         3.2.6.9 Hill Climbing 56
         3.2.6.10 Greedy Algorithm 56
         3.2.6.11 Memetic Algorithm 57
   3.3 Previous Work To Solve Network Design Problem 58

4. Genetic Algorithm 63
   4.1 General Structure of a Genetic Algorithm 63
   4.2 Exploitation and Exploration 65
6.1.5 Genetic Operator Applications

6.1.5.1 Crossover 157
6.1.5.2 Mutation 158

6.1.6 Termination 160

6.2 Experimental Result 164

6.2.1 Experiment based on Crossover Operator for small Network 166
6.2.2 Experiment based on Selection Operator 173
6.2.3 Experiment based on Crossover for Large Network 175
6.2.4 Experiment based on Mutation Operator 177

6.3 Code developed in MATLAB 179

7. **GA approach to solve Shortest Path and TSP Problem** 217

7.1 Shortest Route Problem Presentation 218

7.1.1 Initialization of Parent Population 220
7.1.2 Evaluation 221
7.1.3 Fitness Function 221

7.1.3.1 Self Loop 221
7.1.3.2 Degree Constraint 222
7.1.3.3 Isolated Edge 223
7.1.3.4 Hamiltonian Cycle 224

7.1.4 Result of Fitness Function 225

8. **Conclusion and Future Scope** 229

Bibliography 232

Publications 237