Contents

List of figures xi
List of tables xiii
List of algorithms xv
List of symbols xvii

1 Introduction 1

2 Background and motivation 7
  2.1 Multi-project management ........................................ 7
  2.2 Multi-skilled workers and flexibility design .................... 17
  2.3 Why small project teams? ........................................ 27

3 Problem definitions and basic notation 39
  3.1 Setting of the problems ........................................... 39
  3.2 The project selection problem .................................... 43
  3.3 The workforce assignment problem ................................ 46
  3.4 The utilization leveling problem .................................. 48

4 Optimization models and complexity analysis 53
  4.1 An integrated approach vs. a hierarchical planning approach 53
  4.2 A model for the project selection problem ....................... 56
  4.3 Models for the workforce assignment problem and their limitations 58
    4.3.1 Two alternative models for the workforce assignment problem 58
    4.3.2 Limitations of the assignment models and potential remedies and extensions 63
  4.4 Two alternative models for the utilization leveling problem .... 68
  4.5 A monolithic model for all three problems ....................... 71
  4.6 Complexity analysis ............................................. 73
    4.6.1 Basic concepts of complexity theory ......................... 74
    4.6.2 Complexity of the project selection problem ............... 79
    4.6.3 Complexity of the workforce assignment problem .......... 81
    4.6.4 Complexity of the utilization leveling problem .......... 86
    4.6.5 Summary of results ........................................ 86

5 Literature review 87
  5.1 Work related to the project selection problem .................. 87
  5.2 Work related to the workforce assignment problem .............. 92
5.3 Work related to the utilization leveling problem .......................... 103

6 Solution methods 109

6.1 Exact solution methods and their support ........................................... 110
   6.1.1 Valid inequalities for the workforce assignment problem ............... 111
   6.1.2 A polynomial-time algorithm for the utilization leveling problem ...... 121

6.2 Heuristic solution methods for the workforce assignment problem .......... 124
   6.2.1 A greedy randomized assignment procedure (GRAP) ....................... 127
   6.2.2 An iterated simultaneous assignment procedure (ISAP) ..................... 141
   6.2.3 A drop procedure (DROP) ....................................................... 148
      6.2.3.1 Origin and outline of DROP .............................................. 149
      6.2.3.2 Representation of a remaining LP as a generalized minimum cost flow problem .................. 157
      6.2.3.3 Implementation of the generalized network simplex method 161
      6.2.3.4 Discussion of the implementation ...................................... 181
      6.2.3.5 Properties and modifications of DROP .................................. 186
   6.2.4 A rounding procedure (ROUND) and a relax-and-fix approach ............ 189

7 Numerical analysis 197

7.1 Generation of test instances ......................................................... 198
7.2 Analysis for the project selection problem ....................................... 205
7.3 Analysis for the workforce assignment problem .................................. 223
   7.3.1 Analysis of exact methods and of their support ........................... 226
   7.3.2 Analysis of heuristic methods .............................................. 244
7.4 Analysis for the utilization leveling problem ................................... 273

8 Discussion 275

9 Summary and outlook 281

Bibliography 285