



NURSE ROSTERING Focus on models or algorithms?

Greet Vanden Berghe KU Leuven CHOIR in Practice, 22 November 2013



Taxonomy personnel rostering

A.T. Ernst et al. (2004), Staff scheduling and rostering: A review of applications, methods and models, *EJOR* 153:3-27

- Rostering
 - Demand modelling
 - Shift based demand
- Days off scheduling
- Shift scheduling
- Task assignment
- Staff assignment

J. Van den Bergh, J. Beliën, P. De Bruecker, E. Demeulemeester, L. De Boeck (2013), Personnel scheduling: A literature review



Definition

Nurse rostering

Distribute shifts over the qualified members of staff in order to meet the coverage requirements, taking into account legal and contractual constraints and personal preferences.





Datasets

| Home | Reference Collections |
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| History | 22nd of Jun, 2010 |
| News | A List of Recent Papers in Nurse Rostering (Feb 2007) Online Resources Database - at the |
| Past events | PLANET Network |
| Application Areas | Practice and Theory of Automated Timetabling - The Bibliography |
| Educational timetabling | WATT Bibliography updated up to 1996 and ordered by author |
| Employee timetabling | Comprehensive bibliography (in BibTeX) compiled by Jeffrey Kingston |
| Sports timetabling | |
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| WATT Digests | Benchmark Data Sets |
| Archive | Benchmark Data Sets Staff Rostering - Problem instances and solution verifier graphical user interface |
| WATT Digests Archive WATT Membership | Benchmark Data Sets Staff Rostering - Problem instances and solution verifier graphical user interface Employee Timetabling Problems - Problem generator and solver |
| WATT Digests Archive WATT Membership Why join? | Benchmark Data Sets Staff Rostering - Problem instances and solution verifier graphical user interface <u>Employeer Instabling Problem</u> s, -Problem generator and solver <u>Nurse Rostering</u> - Problem Instances archive |
| WATT Digests Archive WATT Membership Why Join? How to Join? | Benchmark Data Sets Saff Rostering - Problem Instances and solution verifier graphical user interface Employee Timetabling Problems - Problem generator and solver Narse Rostering - Problem Instances archive Narse rostering at QMC, NetUngham |
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| WATT Digests Archive WATT Membership Why Join? How to Join? Current members Contact Us | Benchmark Data Sets Staff Rostering - Problem instances and solution verifier graphical user interface Employee Timetabling Problems - Problem generator and solver Nurse Rostering - Problem instances archive Narres rostering a CMC, Nottingham Shift Scheduling architer, Nottingham Shift Scheduling architer, Nottingham Nurse Rostering - Problem Instances Archive |

Related Resources Personnel Scheduling Research, at the University of Nottingham

Contact:

For further information, please contact Dr. Timothy Curtois (HTTP, e-mail)

29th of November, 2010



Nurse rostering competition 2010



S. Haspeslagh et al. (to appear) The first international nurse rostering competition 2010, Annals of OR



Web of Knowledge





10 most cited papers

Title: Physician staffing patterns and clinical outcomes in critically III patients - A systematic review Author(s): Pronovost, PJ; Angus, DC; Dorman, T; et al. Conference: Society-of-Critical-Care-Medicine-Educational-and-Scientific Symposium Location: ORLANDO, FLORIDA Date: FEB 12-16, 2000 Sponsor(s): Soc Crit Care Med Source: JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION Volume: 288 Issue: 17 Pages: 2151-2162 DOI: 10.1001/jama.288.17.2151 Published: NOV 6 2002 TINE: SOLVING AIRLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT Author(s): HOFFMAN, KL: PADBERG, M Source: MANAGEMENT SCIENCE, Volume: 39, Issue: 6, Pages: 657-682, DOI: 10.1287/mnsc.39.6.657, Published: JUN 1993 3. Title: Staff scheduling and rostering: A review of applications, methods and models Author(s): Ernst, AT; Jiang, H; Krishnamoorthy, M; et al. Source: EUROPEAN JOURNAL OF OPERATIONAL RESEARCH Volume: 153 Issue: 1 Pages: 3-27 DOI: 10.1016/S0377-2217(03)00095-X Published: FEB 16 2004 Title: Virtually perfect time sharing in dual-task performance: Uncorking the central cognitive bottleneck Author(s): Schumacher, EH: Seymour, TL: Glass, JM: et al. Source: PSYCHOLOGICAL SCIENCE Volume: 12 Issue: 2 Pages: 101-108 DOI: 10.1111/1467-9280.00318 Published: MAR 2001 5. Title: A tabu-search hyperheuristic for timetabling and rostering Author(s): Burke, EK: Kendall, G: Soubeiga, E Source: JOURNAL OF HEURISTICS Volume: 9 Issue: 6 Pages: 451-470 DOI: 10.1023/B:HEUR.0000012446.94732.b6 Published: DEC 2003 Title: The state of the art of nurse rostering Author(s): Burke, EK: De Causmaecker, P: Vanden Berghe, G: et al. Source: JOURNAL OF SCHEDULING Volume: 7 Issue: 6 Pages: 441-499 DOI: 10.1023/B: JOSH.0000046076.75950.0b Published: NOV-DEC 2004 7. Title: ANALYSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Author(s): DEXTER, F: TINKER, JH Source: ANESTHESIOLOGY Volume: 82 Issue: 1 Pages: 94-101 DOI: 10.1097/00000542-199501000-00013 Published: JAN 1995 THE: SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Author(s): WARNER, DM Source: OPERATIONS RESEARCH Volume: 24 Issue: 5 Pages: 842-856 DOI: 10.1287/opre.24.5.842 Published: 1976 Title: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS • Author(s): BOEHM, BW: PAPACCIO, PN Source: IEEE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 10 Pages: 1462-1477 DOI: 10.1109/32.6191 Published: OCT 1988 10. Title: Emergency logistics planning in natural disasters Author(s): Ozdamar, L; Ekinci, E; Kucukyazici, B Conference: Biennial Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Aussois, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 1-4 Pages: 217-245 DOI: 10.1023/B:ANOR.0000030690.27939.39 Published: JUL 2004



Health care

| 1. | The Origician staffing patterns and clinical outcomes in critically III patterns - A systematic review MuNOTY How and Linear PCF Control (1997) MuNOTY How and Clinical Control (1997) MuNOTY HOW AND |
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| 2. | Tife: SOLVING AIRLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT Althor(IS), HOFFMAK, KL, PADERKO, M Source: MANAGEMENT SCIENCE: Volumin: 39 Issue: 6 Pages: 657-6482 DOI: 10.1827/mmsc.39.6.657 Published: JUN 1993 |
| 3. | Tale: 5 Bit Scholdling and robating: A trykwe of spplications, methods and models Adhol(1): Emst. Jang, H Krishmanothy, Mattal. Source: EUROPEMJ.JORNAL OF OPERATIONAL RESEARCH Volume: 13 Issue: 1 Pages: 3-27 DOI: 10.1016/80377-2217(03)00095-X Published: FEB 16 2004 |
| 4 . | Trie: Virinality partice, Lime abating in dual-basic parformance: Uncerking the central cognitive bottleneck Author(s) Schumacher, Er, Seymour, TL, Glass, M, et al. Source: PSYCHCACAL, SCENCE Volume: 1 Issue: 2 Pages: 101-108 DOI: 10.1111/1467-9280.0318 Published: MAR 2001 |
| 5. | Tele: A tabus-search hyperheutritic for timetabiling and rostering Author(s): Buke, EX: Kendal, O. Skouheiga, E. Soure: JOUTNAU, OH FEUNRTICS: Volume: 9 Issue: 6 Pages: 451-476 DOI: 10.1023/B:HEUR.0000912446.94732.36 Published: DEC 2003 |
| 6. | The state of the art of nurse restances Author(18) Binks, EX-DEC CalimaneSke, P. Vanden Berghe, G. et al. Source: JOURNA, CS-SCHEDU, INS Volume: T Issue: # Pages: 441-499 DOI: 10.1023/B:JOSH.8000044676.75950.0b Published: NOV-DEC 2004 |
| 7. | Title: ANALYSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Author <u>10 DEFERT (THINET AU</u> Source ANESTRESECOGY Volume : 1 Pages: 94-101 DOX 10.1097/00000542-199501009-00013 Published: JAN 1995 |
| 8. | TISE: SCHEDULINE NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Author(s): WARNER, DM Sourc: COPERITOR RESEARCH Volume: 24 Issue: 5 Pages: 642-554 DOI: 10.1287/opre.24.5.842 Published: 1976 |
| 9. | Title: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Author(s): DECHIN, BW, PARACION PN Source: IECE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 19 Pages: 1462-1477 DOI: 10.1109/32.6191 Published: OCT 1988 |
| 10. | Tate: Emregency legiblice planning in natural disaters Abhrolis, Octamor, Elsinci, Excussiver, B Conference: Blendal Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Locator: Aussois, FRANCE Date: JUN 17-22, 2091 Source: ANNLAS COFERATION REREARCH Volume: 12 Issue: 14 Pages; 217-245 DOI: 10.1023/B.ANDR.000030690.27393.39 Published: JUL 2004 |



Logistics

| □ 1. | The: Physician staffing patterns and clinical outcomes in critically ill patients - A systematic review Adhrots) Phonoson PA Anguo, DC, Channa, Tatal. Mahrots, Phonoson, PA Anguo, DC, Channa, Tatal. Source: JMAJ-2010NLA CPT EALERCEACAM JEDCAL ASSOCIATION Volume: 281 Issue: 17 Page: 2151-2162. DOI: 10.1091/gma.288.17.2151 Published: NOV 2202 |
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| 2. | Title: SOLVIN-SAIRLINE CREW SCHEDULUW PROBLEMS BY BRANCH-AND-CUT Althor(II), HOFFMAR, RL: PHODERTO, III Source: MANAGEMENT SOEDREC Volume: 39 Issue: 6 Pages: 657-682 DOI: 10.1287/mnsc.39.6.657 Published: JUN 1993 |
| 3. | Tale: Staff scheduling and roskefnig: A review of applications, methods and models Aubroty: Emc.At. Jung H. Krishmanovity M. et al. Source: EUROPEAN JOURNAL OF OPERATIONAL RESEARCH Volume: 13 Issue: 1 Pages 3-27 DOI: 10.1916/80377-2217(03)0095-X Published: FEB 16 2004 |
| 4. | Tale: Virhauly serifict lime sharing in dual-task performance: Uncerking the sentral cognitive bottlenack Autority: Source: Eff Seynocu: (C. Gass, M. et al. Source: PSYCHOLOGICAL SCIENCE Volume: 12 Issue: 2 Pages: 101-108 DOI: 10.1111/1467-0280.00318 Published: MAR 2001 |
| 5. | Titler, A bau-sanch hyperheurstille for timeballing and rostering Aubroty): Bains, F. Kondall, G. Soubaga, E. Source: JOURNAL OF HEURISTICS Volume: 9 Issue: 6 Pages: 451-476 DOI: 10.1023/B:HEUR.0000012446.94732.86 Published: DEC 2003 |
| 6. | Tale: The state of the art of nume rotating Autority) Brink: EDE Courseaceter, Winden Berghe, G. et al. Source: JOURNAL OF SCHEDULING Volume: 7 Issue: 6 Pages: 441-499 DOI: 10.1023/BIJOSH.0000046676.75950.0b Published: NOV-DEC 2004 |
| 7. | Tate: ANALVSIS OF STRATEGUES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Aubricyli DOXTRF, FINRER, JH Source: ANESTHESIOLOGY Volume: 12 Issue: 1 Pages: 94-101 DOI: 10.1097/00000542.199501000-00013 Published: JAN 1995 |
| 8. | Tate: SCHEDULING KURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Aldive(s): WINNEN, DM Source: OPERATORIS RESEARCH Volume: 24 Issue: 5 Pages: 542-556 DOI: 10.1287/opre.24.5.442 Published: 1976 |
| 9. | Tate: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Aubrich; BOEM, MIX: PRAPACIC, OR Source: EEEE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 19 Pages: 1462-1477 DOI: 10.1198/02.6191 Published: OCT 1988 |
| 10. | Ties <u>Congregency legistics planning</u> , natural disaters Audroly: OtaBarnet, Leonce, Excossivato, B Conference: Biendal Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Aussols, FRANCE Date: JUN 17-22, 2011 Source: XINULS OF OPERATIONS RESEARCH Volume: 12 Issue: 14 Pages 217-345 DOI: 10.1023/BLANCR.00003306927733.38 Published: JUL 2004 |



Surveys

Title: Physician staffing patterns and clinical outcomes in critically III patients - A systematic review Title: Physician statility passes to company, T; et al. Author(s): Pronovost, PJ; Angus, DC; Dorman, T; et al. Conference: Society-of-Critical-Care-Medicine-Educational-and-Scientific Symposium Location: ORLANDO, FLORIDA Date: FEB 12-16, 2000 Sponsor(s): Soc Crit Care Med Source: JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION Volume: 288 Issue: 17 Pages: 2151-2162 DOI: 10.1001/jama.288.17.2151 Published: NOV 6 2002 Title: SOLVING AIRLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT 2. Author(s): HOFFMAN, KL: PADBERG, M Source: MANAGEMENT SCIENCE Volume: 39 Issue: 6 Pages: 657-682 DOI: 10.1287/mnsc.39.6.657 Published: JUN 1993 3. Title: Staff scheduling and rostering: A review of applications, methods and models Author(e): Emst, AT, Jiang, H; Krishnamoorthy, M; et al. Source: EUROPEAN JOURNAL OF OPERATIONAL RESEARCH Volume: 153 Issue: 1 Pages: 3-27 DOI: 10.1016/S0377-2217(03)00095-X Published: FEB 16 2004 4. Title: Virtually perfect time sharing in dual-task performance: Uncorking the central cognitive bottleneck Author(s): Schumacher, EH: Seymour, TL: Glass, JM: et al. Source: PSYCHOLOGICAL SCIENCE Volume: 12 Issue: 2 Pages: 101-108 DOI: 10.1111/1467-9280.00318 Published: MAR 2001 Title: A tabu-search hyperheuristic for timetabling and rostering 5. Author(s): Burke, EK; Kendall, G; Soubeiga, E Source: JOURNAL OF HEURISTICS Volume: 9 Issue: 6 Pages: 451-470 DOI: 10.1023/B:HEUR.0000012446.94732.b6 Published: DEC 2003 Title: The state of the art of nurse rostering . . Author(s): Burke, EK; De Causmaecker, P; Vanden Berghe, G; et al. Source: JOURNAL OF SCHEDULING Volume: 7 Issue: 6 Pages: 441-499 DOI: 10.1023/B: JOSH.0000046076.75950.0b Published: NOV-DEC 2004 7. Title: ANALTON S. Author(s): DEXTER, F; TINKER, JH Title: ANALYSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Source: ANESTHESIQLOGY Volume: 82 Issue: 1 Pages: 94-101 DOI: 10.1097/00000542-199501000-00013 Published: JAN 1995 B. THE: SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Author(s): WARNER, DM Source: OPERATIONS RESEARCH Volume: 24 Issue: 5 Pages: 842-856 DOI: 10.1287/opre.24.5.842 Published: 1976 a Title: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Author(s); BOEHM, BW; PAPACCIO, PN Source: IEEE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 10 Pages; 1462-1477 DOI: 10.1109/32.6191 Published: OCT 1988 10. Title: Emergency logistics planning in natural disasters Author(s): Ozdamar, L: Ekinci, E: Kucukvazici, B Conference: Biennial Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Aussois, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 1-4 Pages: 217-245 DOI: 10.1023/B:ANOR.0000030690.27939.39 Published: JUL 2004



Algorithms

| Tais: Physician staffing patterns and clinical outcomes in critically ill patterns - A systematic review Adminity (Newport, P. Angus, D. Cham, T. Hai, Adminity (Newport, P. Angus, D. Cham, T. Hai, Sonare, J. MAJ, OLIVAL, Of The AMERICAN MEDICAL ASSOCIATION Volume: 288 Issue: 17 Page: 219-219-219, 200-10-1094/jama.28.17.2191 Published: NOV 6 2002 |
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| Title: SOLVING AIELINE CREW SCHEDULING PROELENS BY BRANCH-AND-CUT Autor(1): HOFFMAN, KL: PADEERG, M Source: MANAGENT SCENCE Volume: 39 Issue: 6 Pages: 657.482 DOI: 10.1287/mmsc.39.6.657 Published: JUN 1993 |
| Time: Baff scheduling and rostering: A royive of opplications, methods and models Author(s): Time: Ariam, P. Krishannovity, M. et al. (Second Scheduling): Source: EUROPEAN JOURNAL OF OPERATIONAL RESEARCH Volume: 153 Issue: 1 Pages: 3-27 DOI: 10.1016/S0377-2217(03)00095-X Published: FEB 16 2004 |
| The: "Utrivially perfect line sharing in dual-task performance: Uncorking the central cognitive bottleneck Anthor(s): Stummote, EV Symous, U. Gans, M. et al. Source: PSYCHOLOGICAL SCIENCE: Volume: 12 Insuz: 2 Pages: 101-108 DOI: 10.1111/1467-9280.00318 Published: MAR 2001 |
| Cale: A tabusearch hyperheuristic for ametabling and rostering Annoving tomm: PC: Nemanrix Globaleya. E Source: J.OUMM. of HEURISTIC Source: 0 Heuristics Counce: 0 Pages: 451-476 DOI: 10.1023/B:HEUR.0000012446.94732.MF Published: DEC 2003 |
| Tils: The state of the art of nurse rootering Autom(s), Bunk, BC Gausanaedat, P; Vanden Berghe, O; et al. Source: JOUMNAL OF SchEDULING Volume: 7 I source: 1 Pages: 441-499 DOI: 10.1023/B:JOSH.000044676.75950.0b Published: NOV-DEC 2004 |
| Tile::ANALVSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Authon(s) CEXTER, F, TINKER, JH Source: ANESTHESIO,COY Volume: \$2 Issue: 1 Pages: 94-191 DOI: 10.109700000542.199501009-00013 Published: JAN 1995 |
| Tide: SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE WATHEMATICAL-PROGRAMMING APPROACH Authority: WWINER, DM Source: DFERMION RESEARCH Volume: 24 Issue: 5 Pages: 842-856 DOI: 10.1287/opre.24.5.842 Published: 1976 |
| Tile: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Automic): BOEHM, BW, PAPACCIO, PM Source: IEEE TWARCHTORS OF SOFTWARE ENGINEERING Volume: 14 Issue: 19 Pages: 1462-1477 DOI: 10.1109/02.6191 Published: OCT 1988 |
| Tide: Emergency logistics planning in natural disasters Author(s) Ozdamar, L.; Eknic, E.; Rucokyazici, B. Zudhor(s) Ozdamar, L.; Eknic, E.; Rucokyazici, B. Conference: Elemania Workhop on Models and Adportitions for Planning and Scheduling Problems (MAPSP) Location: Aussoin, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 14. Pages: 217-245 DOI: 10.1023/B;ANOR.000003069627393.39 Published: JUL 2004 |
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Psychology

| 2 Tes-SQLYNCA ARLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT Abbrock: DEVERAM, RL, PORERGA M Subscription (Comparison of the Comparison of the Compa | □ 1. | The: Physician staffing patterns and clinical outcomes in critically ill patients - A systematic review Adm/styl; Phonorow, Y. Alega, DC; Coursen, T. et al., Adm/styl; Phonorow, Y. Alega, DC; Coursen, T. et al., Security, JMA, 2007, Conf. Care Med. Security, Staffing and Sta |
|--|-------|--|
| The Staff scheduling and rotering: A review of applications, methods and models Advorts: EUROPEAN JOURNAL, OF OPEENTIONAL RESEARCH Wolume: 133 Issue: 1 Pages: 32-7 DOI: 10.1016/B03077-2217(03)00095-X Published: PEB 16.2004 Advorts: EUROPEAN JOURNAL, OF OPEENTIONAL RESEARCH Wolume: 133 Issue: 1 Pages: 32-7 DOI: 10.1016/B03077-2217(03)00095-X Published: PEB 16.2004 Advorts: EUROPEAN JOURNAL, OF OPEENTIONAL RESEARCH Wolume: 133 Issue: 1 Pages: 32-7 DOI: 10.1016/B03077-2217(03)00095-X Published: PEB 16.2004 Advorts: EUROPEAN JOURNAL, OF OPEENTIONAL AND CONTROLLING AND ISSUE: Pages: 14-10 The A fabric-sarch Tuyperhourse: EUROPEAN ISSUE: Pages: 14-108 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-108 DOI: 10.1111/1447-0288.09318 Published: MAR.2001 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-149 DOI: 10.1023/BHEUK.0000012446.34732.bB Published: DBE 2003 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-149 DOI: 10.1023/BHEUK.0000012446.34732.bB Published: DBE 2003 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-149 DOI: 10.1023/BHEUK.0000012446.34732.bB Published: DBE 2003 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-149 DOI: 10.1023/BHEUK.0000012446.34732.bB Published: DBE 2003 Advorts: Burke EV Kondia (G) Storesses: Pages: 14-149 DOI: 10.1023/BHEUK.0000012446.34732.bB Published: NOV.OBE 2004 The: CANALYIS OF STRATECIES O DECREASE FOSTANEETHESIA CARE UNIT COSTS Source: JOURINAL OF SCHEDULING Volume: 14 Pages: 24-199 DOI: 10.1023/BH2UK.0000044675.79500.ab Published: JAN 1995 The: SCHEDULING NURSING PERSONEL ACCORDINO TO NURSING PERFERENCE - MATTHEWATICAL-PROGRAMMING APPROACH Advorts: DEFRATADING AND CONTROLLING SOFTWARE 24-2455 DOI: 10.1327/09FF442-1477 DOI: 10.101932.2191 Published: OCT 1988 The: EUROPERATADING AND CONTROLLING SOFTWARE EORS The: EUROPERATADING SOFTWARE EORS The: EUROPERATADING SOFTWARE EORS | 2. | Title: SOLVING AIRLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT Althor(s): HAPPIRAN, KL, IMADERO, M Source: MANAGRAPHY SOLENCE Volume: 39 Issue: 6 Pages: 657-682 DOI: 10.1287/mmsc.39.6.657 Published: JUN 1993 |
| A The VIrbuilty perfect line shafing in dual-six performance. Uncohing the central cognitive bottleneck Advorts: Networks CF Netw | 3. | Tate: Staff scheduling and rookening: A evidee of applications, methods and models Author(s): Emut, AT, Jang, H: Krishnamoothy, M; et al. Source: EUROPENJORNAR of CREMENTONI, RESEARCH Volume: 153 Issue: 1 Pages: 3-27 DOI: 10.1016/603377-2217(03)00095X Published: FEB 16 2004 |
| Star A baby-sarch hyperheutistic for filmstabiling and roskning Authority: Burke, EK Kondia (J. Stonlegia, E. Source: JOURNAL OF HEURISTICS Volume: 9 Issue: Frages: 451-72 DOI: 10.1023/B:HEUR.0000012446.34732.b6 Published: DEC 2003 Authority: Burke, EK Kondia (J. Stonlegia, E. Source: JOURNAL OF CHEURISTICS Volume: 7 Issue: Frages: 451-72 DOI: 10.1023/B:HEUR.0000012446.34732.b6 Published: DEC 2003 Control (J. Star, Test Source: JOURNAL OF CHEURISTICS Volume: 7 Issue: Frages: 451-72 DOI: 10.1023/B:HEUR.0000012446.34732.b6 Published: DEC 2003 Control (J. Star, Test Source: JOURNAL OF CHEURISTICS Volume: 7 Issue: Frages: 451-73 DOI: 10.1023/B:HEUR.00000460757959.06 Published: NOV.OEC 2004 Test ANADYSIS OF STRAFECIES TO DECREASE FOSTANESTHESIA CARE UNIT COSTS Advorts: DECRET: F. TINKER, T. Starker, F. Pages: 441-419 DOI: 10.1027/8000542-19990100-00013 Published: JAN 1995 Test: SCHEDULING NIKSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: NURSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Source: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERSONNEL ACCORDING The: DURING NIKSING PERSONNEL ACCORDING TO NURSING PERSONNEL Source: SUMMER'S NURSING PERSONNEL ACCORDING TO NURSING PERSONNEL Source: SUMMER'S NURSING PERSONNEL ACCORDING TO NURSING PERSONNE The: DECRETAGE NUMBER SOURCE NUME: 10 Pages: 1462-1477 DOI: 10.1028/JAVG8 Source: SUMMER'S NURSING PERSONNE SOURCE NUME: 10 Pages: 1462-1477 DOI: 10.1028/BAVG8 Source: SUMMER'S NURSING PERSONNE VERAMING PERSONN | 4. | Tate: Virtually perfect line advine in dual-basic performance: Uncorking the central cognitive bottleneck Adving: Semandary CIT: Symmed. Giss, Mc et al. Source PSYCHOLOGICAL SCIENCE: Johann 12: Issue 2: Pages: 101-108. DOI: 10.1111/1467-8289.80318. Published: MAR 2001 |
| Comparison of the state of the store of | 5. | Tate: A bab-search hyperheuristic for timebabiling and rostering Author(1): Buth: 5: Kondall, 6: Schoolega, E. Sacre: JOURNAL OF HEURISTICS Volume: 9 Issue: 4 Pages: 451470 DOI: 10.1023/B:HEUR.0000012446.54732.56 Published: DEC 2003 |
| Tete - NALVSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Advordsj: DVETRE, FTINKEN, H Source: AVESTHESIA(CACY Volume: 28 Issue: 1 Pages: 34-101 DOI: 10.1097/8009342-11951090-00013 Published: JAN 1995 Tete: SUPERITORN RESIDENCE ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Madvordsj: VARNER, DM Source: OPPERITORN RESEARCH Volume: 28 Issue: 5 Pages: 34-24-55 DOI: 10.287/oper.24.54-24 Published: 1976 Tete: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Advordsj: VARNER, DM Source: OPVERTORN RESEARCH Volume: 14 Issue: 10 Pages: 1442-1477 DOI: 10.1093/2.6191 Published: OCT 1988 Source: EXTERNAL TORMO GOFTWARE ENGINEERING Volume: 14 Issue: 10 Pages: 1442-1477 DOI: 10.1093/2.6191 Published: OCT 1988 Comment: Elstein, | □ 6. | Tate: The state of the art of numer rotating Author(s) Burks, EC: De Caustrascker, P. Vanden Berghe, G. et al. Source: JOURNAL OF SCHEDULING Volume. 7 Issue: 6 Pages: 441-499 DOI: 10.1023/BJJOSH.0000044676.75950.0b Published: NOV-DEC 2004 |
| Enter SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Advortight VARMER, DM Source: OPERATIONS RESEARCH Volume: 24 Issue: 5 Pages: 442-456 DOI: 10.1287/6pre.24.5442 Published: 1976 Test: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Advortight Decomposition of the state of | □ 7. | Title: ANALYSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Admor(s) (DXTER, P; TINKER, H) Source: ANESTHESTECLOGY Volume: 21 Issue: 1 Pages: 94-101 DOI: 10.1997/80000542-199591000-00013 Published: JAN 1995 |
| The UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Authority: SoftM, MY, PAPACOD, NI Source: IEEE TRANSACTONES ON SOFTWARE ENGINEERING Volume: 14 Issue: 10 Pages: 1462-1477 DOI: 10.1109/32.6191 Published: OCT 1988 Intel: Emergency logistics planning in natural disasters Authority: Source: Licking (Licking), Clauding and Scheduling Problems (MAPSP) Location: Aussels, FRANCE Date: JUNI 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 12 Issue: 14 Pages: 217-345 DOI: 10.1023/B.ANDR.8000303699.27933.9 Published: JUL 2004 | 8. | Title: SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH Author(s): WARKER, DM Source: OPERATIORS RESEARCH Volume: 24 Issue: 5 Pages: 842-856 DOI: 10.1287/bgre.24.5.842 Published: 1976 |
| Title: Emergency logistics planning in natural disasters Totation(5): Octamar, I: Elson, E: Kouculyatol, B Conference, Binnial Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Ausseis, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 1-4 Pages: 217-245 DOI: 10.1023/BLANCA000030692.7939.39 Published: JUL 2004 | 9. | Title: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS Anthor(Is) BOEHIA, BN), PAPACICIO, PN Source: IECE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 19 Pages: 1462-1477 DOI: 10.119932.6191 Published: OCT 1988 |
| | □ 10. | Title: Emergency logistics planning in natural disasters Author(s): Ocdamar, I.; Ekino, E.; Kucukyazot, B Conference: Biennal Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Aussois, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 14 Pages: 217-245 DOI: 10.1023/B.ANOR.8000030692.27939.39 Published: JUL 2004 |



Software

Title: Physician staffing patterns and clinical outcomes in critically ill patients - A systematic review 1. Author(s): Pronovost, PJ; Angus, DC; Dorman, T; et al. Conference: Society-of-Critical-Care-Medicine-Educational-and-Scientific Symposium Location: ORLANDO, FLORIDA Date: FEB 12-16, 2000 Sponsor(s): Soc Crit Care Med Source: JAMA-JOURNAL OF THE AMERICAN MEDICAL ASSOCIATION Volume: 288 Jssue: 17 Pages: 2151-2162 DOI: 10.1001/Jama.288.17.2151 Published: NOV 6 2002 Title: SOLVING AIRLINE CREW SCHEDULING PROBLEMS BY BRANCH-AND-CUT Author(s): HOFFMAN, KL; PADBERG, M Source: MANAGEMENT SCIENCE Volume: 39 Issue: 6 Pages: 657-682 DOI: 10.1287/mnsc.39.6.657 Published; JUN 1993 3. Title: Staff scheduling and rostering: A review of applications, methods and models Author(s): Ernst, AT: Jiang, H: Krishnamoorthy, M: et al. Source: EUROPEAN JOURNAL OF OPERATIONAL RESEARCH Volume: 153 Issue: 1 Pages: 3-27 DOI: 10.1016/S0377-2217(03)00095-X Published: FEB 16 2004 Title: Virtually perfect time sharing in dual-task performance: Uncorking the central cognitive bottleneck Author(s): Schumacher, EH; Seymour, TL; Glass, JM; et al. Source: PSYCHOLOGICAL SCIENCE Volume: 12 Issue: 2 Pages: 101-108 DOI: 10.1111/1467-9280.00318 Published: MAR 2001 5. Title: A tabu-search hyperheuristic for timetabiling and rostering Author(s): Burke, FK: Kendall, G: Soubeiga, F. Source: JOURNAL OF HEURISTICS Volume: 9 Issue: 6 Pages: 451-470 DOI: 10.1023/B:HEUR.0000012446.94732.b6 Published: DEC 2003 6. Title: The state of the art of nurse rostering Author(s): Burke, EK; De Causmaecker, P; Vanden Berghe, G; et al. Source: JOURNAL OF SCHEDULING Volume: 7 Issue: 6 Pages: 441-499 DOI: 10.1023/B: JOSH.0000046076.75950.0b Published: NOV-DEC 2004 Title: ANALYSIS OF STRATEGIES TO DECREASE POSTANESTHESIA CARE UNIT COSTS Author(s): DEXTER, F; TINKER, JH Source; ANESTHESIQLOGY Volume: 82 Issue: 1 Pages: 94-101 DOI: 10.1097/00000542-199501000-00013 Published: JAN 1995 TIME: SCHEDULING NURSING PERSONNEL ACCORDING TO NURSING PREFERENCE - MATHEMATICAL-PROGRAMMING APPROACH □ s. Author(s): WARNER, DM Source: OPERATIONS RESEARCH Volume: 24 Issue: 5 Pages: 842-856 DOI: 10.1287/opre.24.5.842 Published: 1976 Title: UNDERSTANDING AND CONTROLLING SOFTWARE COSTS 9. Author(s): BOEHM, BW, PAPACCIO, PN Source: IEEE TRANSACTIONS ON SOFTWARE ENGINEERING Volume: 14 Issue: 10 Pages: 1462-1477 DOI: 10.1109/32.6191 Published: OCT 1988 10. Title: Emergency logistics planning in natural disasters Author(s): Ozdamar, L; Ekinci, E; Kucukvazici, B Conference: Biennial Workshop on Models and Algorithms for Planning and Scheduling Problems (MAPSP) Location: Aussois, FRANCE Date: JUN 17-22, 2001 Source: ANNALS OF OPERATIONS RESEARCH Volume: 129 Issue: 1-4 Pages: 217-245 DOI: 10.1023/B:ANOR.0000030690.27939.39 Published: JUL 2004



Where is the theory?



Vehicle routing

TRANSPORTATION SCIENCE

Vol. 43, No. 4, November 2009, pp. 408-416 ISSN 0041-1655 | EISSN 1526-5447 | 09 | 4304 | 0408



DOI 10.1287/trsc.1090.0301 © 2009 INFORMS

Fifty Years of Vehicle Routing

Gilbert Laporte

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The Vehicle Routing Problem (VRP) was introduced 50 years ago by Dantzig and Ramser under the tile "The Truck Dispatching Problem." The study of the VRP has given rise to major developments in the fields of exact algorithms and heuristics. In particular, highly sophisticated exact mathematical programming decomposition algorithms and powerful metaheuristics for the VRP have been put forward in recent years. The purpose of this article is to provide a brief account of this development.

Key words: vehicle routing problem; traveling salesman problem; exact algorithms; heuristics; metaheuristics; survey

History: Received: August 2009; revision received: September 2009; accepted: September 2009. Published online in Articles in Advance October 21, 2009.



Scheduling

Peter Brucker, University of Osnabruck: 29 pages theory

- Single machine problems
- Parallel machine problems without preemption
- ...
- Serial batching problems
- ..
- Flow shop problems with transportation times and a single robot
- ...
- Flow shop problems with a single server



Scheduling

last update: 03.07.06 (SK) http://www.mathematik.uni-osnabrueck.de/research/OR/class

Single machine problems

• maximal polynomially solvable:

| $1 prec; r_i C_{max}$ | Lawler (1973) |
|---|---------------------------------------|
| $1 prec; p_i = p; r_i L_{max}$ | Simons (1978) |
| $1 prec; r_i; pmtn L_{max}$ | Blazewicz (1976), Baker et al. (1983) |
| $1 prec; p_i = p; r_i \sum C_i$ | Simons (1983) |
| $1 prec; pmtn; p_i = p; r_i \sum C_i$ | Baptiste et al. (2004) |
| $1 r_i; pmtn \sum C_i$ | Baker (1974) |
| $1 p_i = p; r_i \sum w_i C_i$ | Baptiste (2000) |
| $1 sp - graph \sum w_i C_i$ | Lawler (1978) |
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| $1 p_i = p; r_i \sum w_i U_i$ | Baptiste (1999) |
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| $1 p_i = p; r_i \sum T_i$ | Baptiste (2000) |
| $1 pmtn; p_i = p; r_i \sum T_i$ | Tian et al. (2006) |
| $1 p_i = 1; r_i \sum w_i T_i$ | Assignment-problem |

• maximal pseudopolynomially solvable:

| $1 r_i; pmtn \sum w_i U_i$ | Lawler (1990) |
|-----------------------------|----------------------------------|
| $1 \sum T_i$ | Lawler (1977), Du & Leung (1990) |

• minimal NP-hard:

 $1|r_i|L_{max}$ Lenstra et al. (1977) * $1|chains; r_i; pmtn| \sum C_i$ Lenstra (-) $1|prec| \sum C_i$ Lawler (1978), Lenstra & Rinnooy Kan (1978) $1|r_i| \sum \overline{C_i}$ Lenstra et al. (1977) $1|chains; p_i = 1; r_i| \sum w_i C_i$ Lenstra & Rinnooy Kan (1980) $1|prec; p_i = 1|\sum w_i \overline{C_i}$ Lawler (1978), Lenstra & Rinnooy Kan (1978) * * $1|r_i; mtn| \sum w_i C_i$ Labetoulle et al. (1984)



Where is the theory?

NP-hard problem

- H.C. Lau (1996) On the complexity of manpower shift scheduling, *Computers & OR*, 23(1): 93-102
- T. Osogami, H. Imai (2000) Classification of various neighbourhood operations for the nurse scheduling problem, *Lecture Notes in Computer Science*, 1969: 72-83
- M. Moz and M. Vaz Pato (2007) A genetic algorithm approach to a nurse rerostering problem (!reference to a Portugese proof), *Computers & OR*, 34: 667-691
- P. Brucker, R. Qu, E.K. Burke (2011) Personnel scheduling: Models and complexity, *EJOR* 210 (3): 467-473
- M. Rocha, J.F. Oliveira, M.A. Carravilla (2013) Cyclic staff scheduling: optimization models for some real-life problems *Journal of Scheduling*, 16 (2): 231-242



Categorisation nurse rostering

| | ł | Personnel constraints | | Skill interactions |
|---------------------------------|--------------|-----------------------|-------|------------------------------|
| | А | Availability | 2, 3, | Fixed number |
| α Personnel environment | \mathbf{S} | Sequences | Ν | Variable number |
| | | B Balance | | Individual skill definitions |
| | \mathbf{C} | Chaperoning | | |
| | (| Coverage constraints | | Shift type |
| | R | Range | 2, 3, | Fixed number |
| β Work characteristics | Т | Time Intervals | Ν | Variable number |
| | V | Fluctuating | Ο | Overlapping |
| | | Objective | | Mode |
| | Ρ | Personnel constraints | Μ | Multi objective |
| γ Optimisation objective | \mathbf{L} | Coverage constraints | | |
| | Х | Number of personnel | | |
| | R | Robustness | | |
| | G | General | | |

P. De Causmaecker, G. Vanden Berghe (2011) A categorisation of nurse rostering problems, Journal of Scheduling, 14(1): 3-16



Where is the rest of the theory?

Personnel scheduling

Can personnel scheduling reach the same academic status as vehicle routing, scheduling?

What do we need?



Effort to establish theory

AI|RVN|G

formulated as integer minimum cost flow problems: **polynomially solvable**

Pieter Smet, Peter Brucker, Patrick De Causmaecker, Greet Vanden Berghe (2013)



Where are the applications?

| Model | Implementation- knowledge source | Still in use | Model type* | Location | Implementation site and number | Product name if commercialized |
|------------------|-------------------------------------|--------------|-------------|-----------------|-----------------------------------|-----------------------------------|
| Δ72107 | Article | Unknown | MP | Saudi Arabia | 1 hospital | |
| Bellanti | Article | Unknown | н | Italy | 1 ward/unit | |
| Liao | Article | Unknown | н | Taiwan | 1 hospital | |
| Weil | Article | Unknown | Ĥ | France | Commercial product | Gymnaste |
| Darmoni | E-mail verification | No | MP | France | 1 hospital | HOROPLAN |
| Dowsland | E-mail verification | No | н | United Kingdom | 1 hospital | |
| Meyer auf'm Hofe | E-mail verification | Yes | MP | Germany | 150 hospitals | ORBIS Dienstplan |
| Bard | E-mail verification | Yes | н | United States | Commercial product | Care Systems Inc. |
| Burke | E-mail verification | Yes | н | Belgium | 40+ hospitals, beginning | PLANE |
| | | | | - | implementation in UK | |
| Cheng | E-mail verification | Unknown | MP | Hong Kong | 1 ward/unit | |
| Diaz | E-mail verification | Yes | н | Brazil | 1 hospital | |
| Isken | E-mail verification | Partially | н | United States | 1 hospital | |
| Kawanaka | E-mail verification | Yes | н | Japan | Some hospitals | |
| Kostreva | E-mail verification | Yes | н | United States | 1 hospital | |
| Van Wezel | E-mail verification | Yes | DS | The Netherlands | Multiple hospitals | ZKR-nurse-scheduling |

Kellogg and Walczak (2007) Nurse Scheduling: From Academia to Implementation or Not?, Interfaces 37(4): 355-369



Not ready yet

Current practice

Iterative academic approach

- Relevant, attractive problems
- Tailored algorithms





Personnel scheduling

Distribute shifts over the qualified members of staff in order to meet the coverage requirements, taking into account legal and contractual constraints and personal preferences.





Time

- scheduling horizon: 4 weeks, 1 month, 13 weeks, ... constraints across subsequent horizons?
- cyclic, semi cyclic, non cyclic schedules
- shift types

start- and end time, overlapping shifts, deviating hours, interrupted duties

| shift type | from | till |
|------------|-------|-------|
| early | 7:00 | 15:00 |
| day | 8:00 | 17:00 |
| late | 13:00 | 21:00 |
| night | 21:00 | 7:00 |





Personnel

skills

training, experience, responsibility, job description, multiple skills

contracts

full time, part time (x %), night nurse, weekend nurse, etc.







Personnel

• skills ... change over time

training, experience, responsibility, job description multiple skills

• contracts ... change over time

full time, part time (x %), night nurse, weekend nurse, etc.



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Coverage requirements

- coverage = number of qualified personnel members per day and per shift type, for the entire scheduling horizon
- minimum coverage hard constraint?
- preferred coverage







Constraints

- legal constraints e.g. minimum rest time hard constraints?
- organisational constraints e.g. no skill downgrading hard constraints?
- contractual constraints e.g. maximum 6 nights per month
- personal constraints/preferences e.g. free Wednesday afternoons



Any feasible solution to the problem?



Evaluation of solutions

| | Мо | Tu | We | Th | Fr | Sa | Su | Мо | Tu | We | Th | Fr | Sa | Su |
|----|----|----|----|----|----|----|----|----|----|----|----|----|----|----|
| P1 | | | | | | Μ | Μ | М | М | L | L | Ν | | |
| P2 | Μ | | | | | | Ν | N | | N | L | L | | |
| P3 | | | | | | | | М | М | М | М | М | М | М |
| P4 | | | | | | | L | М | | L | Ν | N | Ν | |
| P5 | N | | | | | | | ML | L | L | | | | |



Constraint classes

Counters e.g. number of working days

$$v(dwc_{e,D'}) = csv(dwc_{e,D'}) + \sum_{d \in D'} p_{e,d}$$

Series e.g. number of consecutive days worked

$$p(dws_e) = w(dws_e) \sum_{d \in D} max \left\{ \left(\sum_{i=0}^{m(dws_e)} p_{e,d+i} \right) - m(dws_e), 0 \right\}$$

Successive series e.g. number of free days after night shifts

Conditional constraint.

P. Smet et al. (to appear) Nurse rostering: a complex example of personnel scheduling with perspectives, Automated Scheduling: Real World Case Studies, Springer



Consistent constraint evaluation

- constraint definition work stretches or patterns?
- continuity of series constraints regardless of the scheduling period (previous and upcoming planning period)
- contextual evaluation of constraints



Example 1: Counters

Counter penalty

proportional to the constraint violation ... context?

- Employee request
 - 5 free days starting on Feb 1 for a ski vacation
- Grant either all days or not any at all

| Naam | Λ. | Informatie | Ма 18 | Di 19 | Wo 20 | Do 21 | Vr 22 | Za 23 | Zo 24 | Ma 25 | Di 26 | Wo 27 | Do 28 | Vr 29 | Za 30 | Zo 31 | Ma 01 | Di 02 | Wo 03 | Do 04 | Vr 05 | Za 06 | Zo 07 |
|------|----|------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| A | E | 80,70% | V1 | V1 | V1 | V1 | V2 | | | V1 | V2 | V2 | V2 | V1 | | Lt | BV | BV | BV | BV | BV | V1 | V1 |
| | | 9 BF | | | - | | | | | | | | | | | L | - | | | _ | _ | | |
| A | F | 60,09% | | L1 | V2 | V2 | | L1 | V2 | L1 | | | 1 | V2 | | | L2 | L2 | | L2 | | | |
| | | 5 BF | | | | | - | | 1 | | | | 1 | | | | | | | | | | |
| в | K | 60,09% | 11 | | V1 | V1 | | V3 | V1 | V1 L2 | L1 | | | V1 | | | L2 | | L2 | Lt | | | |
| | | 5 BF | | | 15 | | | VZ | | | | | | | | | | | | - | | | |



Example 1: Counters

Counter penalty

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| Naam | / | Informatie | Ma 18 | Di 19 | Wo 20 | Do 21 | Vr 22 | Za 23 | Zo 24 | Ma 25 | Di 26 | Wo 27 | Do 28 | Vr 29 | Za 30 | Zo 31 | Ma 01 | Di 02 | Wo 03 | Do 04 | Vr 05 | Za 06 | Zo 07 |
|------|---|------------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|----------|
| A | Е | 80,70% | V1 | V1 | V1 | V1 | V2 | | | V1 | V2 | V2 | V2 | V1 | | Lt | BV | BV | BV | BV | BV | V1 | V1 |
| 1 | | 9 BF | | | | | | | | | | | | | | L | - | | - | _ | _ | 1 | |
| A | F | 60,09% | | LI | V2 | V2 | | L1 | V2 | L1 | | | | V2 | | | L2 | L2 | | L2 | | | |
| | 5 | 5 BF | | | | | | | | | | | - | | | | | | | | - | | |
| в | к | 60,09% | 11 | | V1 | V1 | | V3 | V1 | | | | L2 | LI | | | V1 | | | L2 | | L2 | Lt |
| | | 5 BF | | | | | | VZ | | | | | | | | | | | | - | | | |



Example 2: Series

- weekdays: Mon Fri
- weekend days: Fri Mon
- weekend constraint: work full weekends

| Fri | Sat | Sun | Mon | |
|-----|-----|-----|-----|---|
| E | E | E | E | |
| | | | | |
| E | E | E | | x |
| | E | E | E | x |
| E | | E | E | x |
| E | E | | E | x |
| E | E | | | x |
| E | | E | | |
| E | | | E | x |
| | E | E | | x |
| | E | | E | x |
| | | E | E | x |
| E | | | | x |
| | E | | | x |
| | | E | | x |
| | | | E | x |



Overtime

Overtime should be compensated within the next three months.

- 1. start counting from the first minute of overtime
- 2. start counting from the shift assignment causing overtime
- 3. start counting from the first Monday after the minute/shift causing overtime
- 4. do not allow additional overtime before the previous overtime has been compensated ... or not?



Overtime

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Accurate data

- hard vs. soft constraints
- constraint weights
- implicit preferences



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• agreement on the data description

Quality of a solution

- monetized objectives
- weighted constraint violations

Weighted sum

$$WO = \sum_{\forall n \in N} \sum_{\forall c \in C} \# violations_{n,c} * weight_c$$

• compensations? unfair objectives, fair variants? fairness measures?

Fairness measures

$$FO = max_n(q_n)$$

$$GO = q_{avg} + \sum_{n \in N} (|q_{avg} - q_n|)$$

$$RO = q_{avg} + max_n(q_n) - min_n(q_n)$$



Weighted sum vs. fairness objectives



Individual roster quality with weighted sum objective function





Constraint weights

Manual vs. Automatic weights



14/18

Mihail Mihaylov and Pieter Smet



Constraint weights

Violations of automatic schedules with manual weights



joint work with Mihail Mihaylov and Pieter Smet



Constraint weights

Violations of automatic schedules: manual vs. extracted weights



joint work with Mihail Mihaylov and Pieter Smet



Algorithmic trends

$$\begin{split} &\sum_{c \in C} w_c n_c \\ &- \left| S \right| \left| K \right| p_{e,d} + \sum_{s \in S} \sum_{k \in K} x_{e,d,s,k} \leq 0 \\ &- p_{e,d} + \sum_{s \in S} \sum_{k \in K} x_{e,d,s,k} \geq 0 \end{split}$$



solution space S









What is the problem with a pool of float nurses?



Workload vs. available staff



Number of shifts to cover

Stefaan Haspeslagh, PhD, 2012



Workload vs. available staff



Increasing availability of nurses

Stefaan Haspeslagh, PhD, 2012



Workload



Wim Vancroonenburg



Tasks vs. shifts



Pieter Smet



Decision levels

- interaction with manpower planning, staffing
- quality of solutions cannot be evaluated without information about the quality of solutions at the other levels



Staffing - scheduling

| Ward | | Skill 1 | Skill 2 | Skill 3 | Skill 4 | Total Nurse | | |
|-----------|-----------------|---------|---------|---------|---------|-------------|--|--|
| Emergency | Primary skill | 1 | 16 | 4 | 6 | 27 | | |
| | Secondary skill | | | | 20 | | | |

| Subgroup | Pattern | No Of Nurses |
|------------------------------|-----------------------------------|--------------|
| | (Primary skill – secondary skill) | |
| Subgroup 1 (G ₁) | Skill 1 | 1 |
| Subgroup 2 (G ₂) | Skill 2 – Skill 4 | 16 |
| Subgroup 3 (G ₃) | Skill 3 – Skill 4 | 4 |
| Subgroup 4 (G ₄) | Skill 4 | 6 |
| | Total | 27 |

Komarudin



Experimental results



Why difficult?

personnel schedulers have been doing it manually for years, why would it be difficult to address the problem with a suitable optimisation approach?

- complexity?
- computation time?
- collection of correct information?
- consistent evaluation of the quality?







A hard problem

automated personnel scheduling

- model: correct and sufficiently generic
- algorithm: produce an acceptable solution



Acknowledgements

Patrick De Causmaecker, Edmund Burke, Sanja Petrovic Peter Brucker, Tim Curtois, Rong Qu, Pieter Smet, Burak Bilgin Stefaan Haspeslagh, Fabio Salassa, Marie-Anne Guerry, Tim De Feyter Komarudin, Mihail Mihaylov, Wim Vancroonenburg Jan Christiaens, Jannes Verstichel

