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A Thesis in a Nutshell: Metaheuristics for Solving Real World Employee Rostering and Shift Scheduling Problems

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Introduction

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  - Overview of Optimisation Strategies Utilized
  - Some results & overview of real-world usage.

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Problem Overview

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- Personnel scheduling is a combinatorial optimization problem often with a vast search space, where exhaustive search and exact solvers are neither viable nor possible within a reasonable time frame.

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- Provided employee & demand data, and objectives, in English.
- Initial problem: defining objectives mathematically.

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    - This included both Shift Scheduling problem & Employee Rostering
- The second problem was to solve an instance of the "roster pattern problem".
- Why separate the two?

Comparison - Personalised Roster

Date	Employee A			Employee B		
	Start Time	**End Time**	**Skill Worked**	**Start Time**	**End Time**	**Skill Worked**
Mon 11th June	0830	1630	Mixology	1630	2200	Culinary
Tues 12th June	0900	1700	Cleaning Tables	1700	2200	Culinary
Wed 13th June	1000	1600	Mixology			
Thurs 14th June	0830	1630	Bouncer			
Fri 15th June	0830	1730	Mixology	1630	2230	Culinary
Sat 16th June				1730	0000	Mixology
Sun 17th June						
X yth Z						

Comparison - Roster Pattern

Date	Roster Pattern 107		Roster Pattern 108	
	Start Time	End Time	Start Time	End Time
Monday 11th June	0830	1630	1630	2200
Tuesday 12th June	0900	1700	1700	2200
Wednesday 13th June	1000	1600		
Thursday 14th June	0830	1630		
Friday 15th June	0830	1730	1630	2230
Saturday 16th June			1730	0000
Sunday 17th June				
Xday yth Z				

Employee	Roster Pattern
Employee A	RP107
Employee B	RP108
Employee n	*RPm*

Problems
Defining Terminology

A roster pattern could look like this for a single employee.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
02/05/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		9am - 5pm	
09/05/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
16/05/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
23/05/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
30/05/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		9am - 5pm	
06/06/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
13/06/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
20/06/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
27/06/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		9am - 5pm	

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Defining Terminology

A personalised roster could look like this for a single employee.

	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
02/05/2022	8am - 4pm		9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	
09/05/2022	9am - 5pm	8am - 4pm	9am - 5pm	9am - 5pm		9am - 5pm	
16/05/2022		8am - 4pm	9am - 5pm	8am - 4pm	8am - 4pm	9am - 5pm	
23/05/2022	9am - 5pm	9am - 5pm		9am - 5pm	9am - 5pm	9am - 5pm	
30/05/2022	8am - 4pm	9am - 5pm	9am - 5pm	9am - 5pm		9am - 5pm	
06/06/2022	8am - 4pm	9am - 5pm	9am - 5pm		9am - 5pm		
13/06/2022	9am - 5pm			9am - 5pm	8am - 4pm	8am - 4pm	
20/06/2022	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm	9am - 5pm		
27/06/2022	9am - 1pm	9am - 5pm	8am - 4pm	9am - 1pm		9am - 5pm	

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7. If specified, a number of shifts defined by a shift rule must exist between upper and lower bounds.
8. Shifts must be of lengths specified by shift rules upper and lower bounds.

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1. Shifts should cover the maximum amount of demand possible.
2. Employees should be allocated to shifts that meet their first skill preference.
3. Employees should be allocated to shifts they have the skill for.
4. Two consecutive rest days for every employee every week.

Solution

A solution which meets the problem specification must traverse a vast search space, must meet legal, contractual and ethical requirements, must attempt to meet specific quality measurements, and must aim to achieve specific goals.

Over my Ph.D., a number of solutions were produced. This is due to requirement changes, and problem re-definition as we learned from previous problem / solution dynamics. So much so that a chapter is dedicated to the variations in the problems and solutions (Chapter 2).

Pseudocode... or not

Algorithm 6.1 Evolutionary Ruin & Stochastic Recreate

```
t ← getParameterisedTemperature()
δ ← getParameterisedDelta()
cr ← getParameterisedCoolingRate()
sr ← getParameterisedSelectionRate()
mr ← getParameterisedMutationRate()
vnsInt ← getVnsInternalIterations()
vnsSeq ← getVnsSequentialIterations()
a = originalSolutionFromFSO()
t′ = t
while t′ > δ do //Exponential Monte-Carlo Acceptance
    b = a.copy()
    f ← decomposition(W) //W are parameterised weightings. Solution decomposition complete.
    a ← selection(a, sr)
    a ← mutation(a, mr) //Evolutionary ruin complete.
    a ← rebuild(a) //Stochastic recreate complete.
    p ← getAcceptanceProbability()
    if p < r then //Random int
        a = b.copy()
        if vnsInt > 0 then
            beginVNS(vnsInt)
        end if
    end if//Solution Acceptance complete.
    t′ *= cr
end while
if vnsSeq > 0 then
    beginVNS(vnsSeq)
end if
```

First solution (Chapter 4)

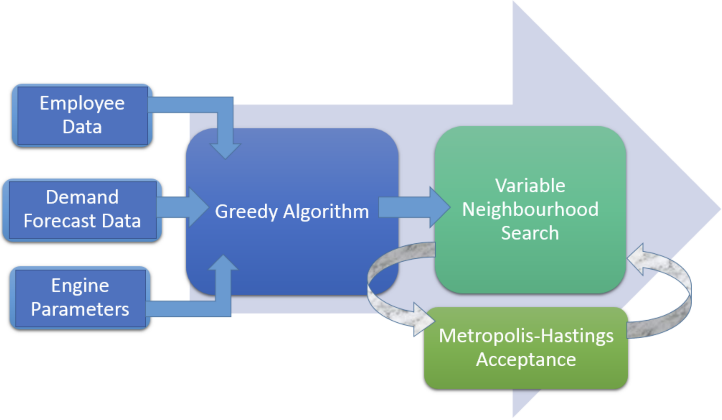


Figure 4.1: Diagrammatic Overview of Algorithm Flow

Second solution (Chapter 5)

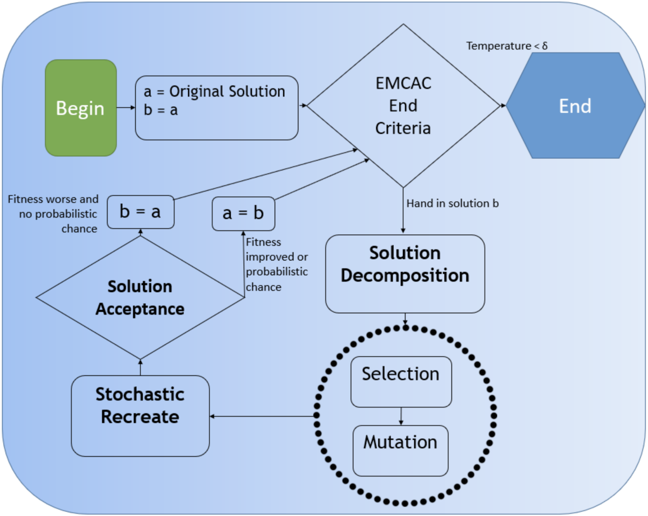


Figure 5.1: Flow Diagram

Third solution (Chapter 6)

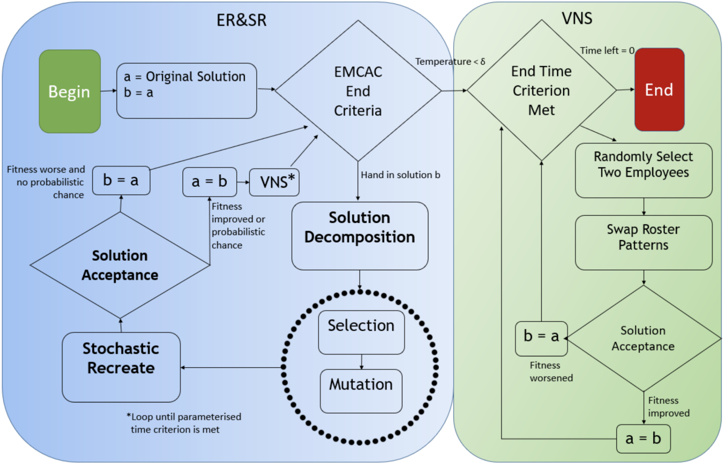
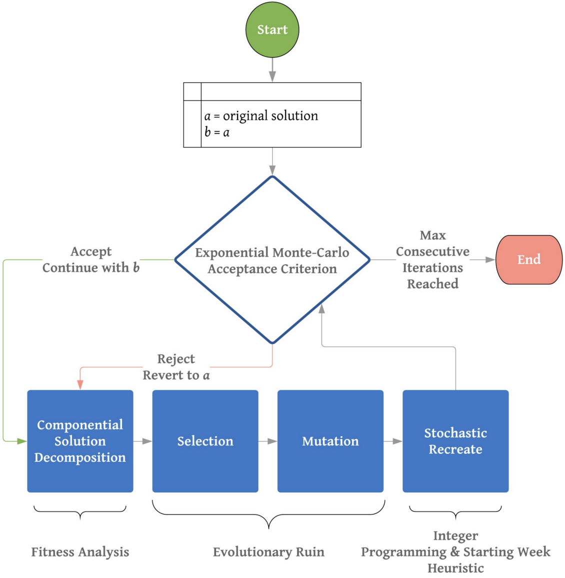


Figure 6.1: Diagrammatic Overview of ER&SR & VNS Hybrid

Fourth solution (Chapter 7)



Results (Fitness)

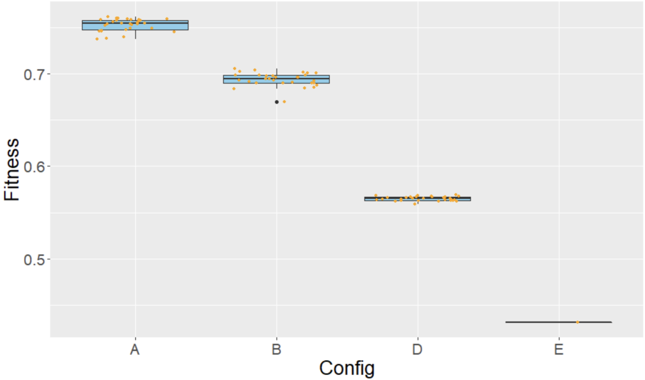


Figure 7.6: Boxplot of Each Configuration Tested 30x With Tuned Parameters

(A) ER&SR with IP

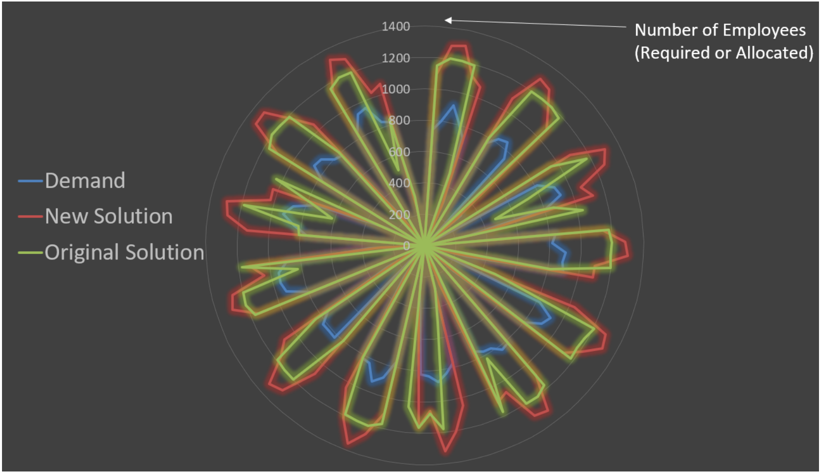
(B) ER&SR only

(C) IP only

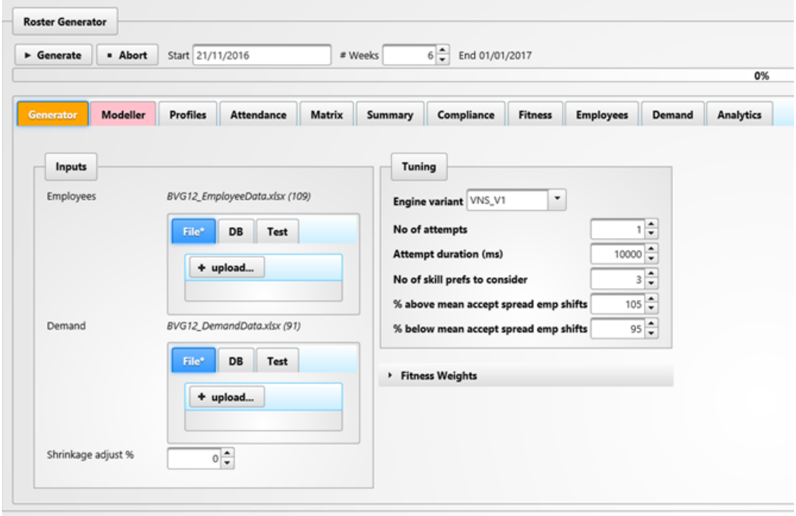
(D) SA only

(E) Baseline

Results (Demand)



Integrated Solutions



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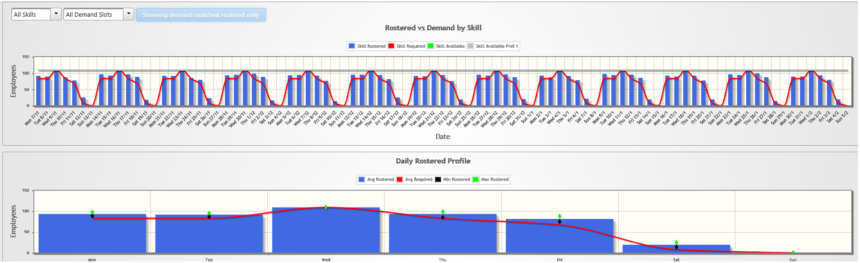


Integrated Solutions

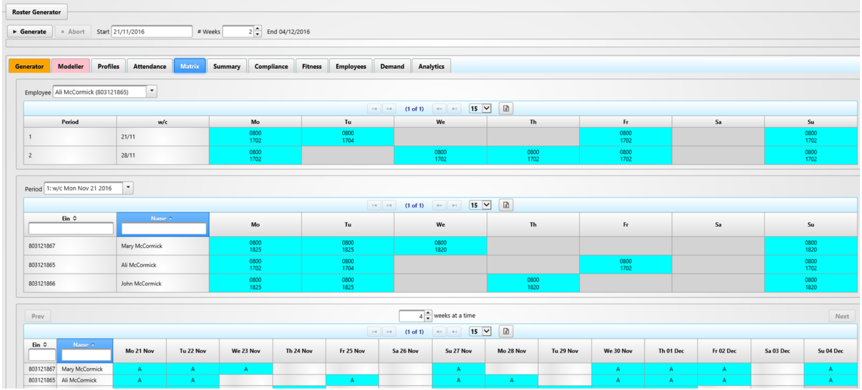
All Demand Slots

(1 of 1) 15

Columns

Day	Date	Ttl Emps	Rostered	NO_SKILL Rost	DRIVER Req	DRIVER Rost	ELECTRICIAN Req	ELECTRICIAN Rost	ENGINEER Req	ENGINEER Rost	PLUMBER Req	PLUMBER Rost
Mon	21/11/2016	3	3	0 (0)	1 (1)	1 (1)	1 (3)	1 (3)	0 (3)	0 (3)	4 (2)	1 (2)
Tue	22/11/2016	3	2	0 (0)	0 (1)	0 (1)	2 (3)	2 (2)	0 (3)	0 (2)	4 (2)	0 (1)
Wed	23/11/2016	3	2	0 (0)	0 (1)	0 (1)	5 (3)	1 (2)	0 (3)	0 (2)	1 (2)	1 (1)
Thu	24/11/2016	3	3	0 (0)	0 (1)	0 (1)	2 (3)	2 (3)	0 (3)	0 (3)	4 (2)	1 (2)
Fri	25/11/2016	3	0	0 (0)	0 (1)	0 (0)	0 (3)	0 (0)	0 (3)	0 (0)	5 (2)	0 (0)
Sat	26/11/2016	3	0	0 (0)	1 (1)	0 (0)	0 (3)	0 (0)	0 (3)	0 (0)	5 (2)	0 (0)
Sun	27/11/2016	3	2	0 (0)	1 (1)	0 (0)	2 (3)	1 (2)	1 (3)	0 (2)	2 (2)	1 (2)
Mon	28/11/2016	3	2	0 (0)	0 (1)	0 (0)	2 (3)	1 (2)	0 (3)	0 (2)	4 (2)	1 (2)
Tue	29/11/2016	3	2	0 (0)	0 (1)	0 (0)	1 (3)	1 (2)	0 (3)	0 (2)	4 (2)	1 (2)
Wed	30/11/2016	3	3	0 (0)	0 (1)	0 (1)	3 (3)	1 (3)	2 (3)	1 (3)	1 (2)	1 (2)
Thu	01/12/2016	3	3	0 (0)	1 (1)	1 (1)	1 (3)	1 (3)	0 (3)	0 (3)	3 (2)	1 (2)
Fri	02/12/2016	3	2	0 (0)	0 (1)	0 (1)	2 (3)	2 (2)	0 (3)	0 (2)	4 (2)	0 (1)
Sat	03/12/2016	3	0	0 (0)	2 (1)	0 (0)	1 (3)	0 (0)	0 (3)	0 (0)	1 (2)	0 (0)
Sun	04/12/2016	3	1	0 (0)	1 (1)	1 (1)	0 (3)	0 (1)	0 (3)	0 (1)	5 (2)	0 (0)
Mon	05/12/2016	3	0	0 (0)	1 (1)	0 (0)	1 (3)	0 (0)	0 (3)	0 (0)	4 (2)	0 (0)
Tue	06/12/2016	3	2	1 (1)	0 (1)	0 (0)	0 (3)	0 (1)	0 (3)	0 (1)	5 (2)	1 (1)
Wed	07/12/2016	3	3	0 (0)	0 (1)	0 (1)	2 (3)	2 (3)	0 (3)	0 (3)	4 (2)	1 (2)
Thu	08/12/2016	3	3	0 (0)	1 (1)	1 (1)	0 (3)	0 (3)	0 (3)	0 (3)	4 (2)	2 (2)
Fri	09/12/2016	3	3	1 (1)	0 (1)	0 (0)	1 (3)	1 (2)	0 (3)	0 (2)	5 (2)	1 (2)
Sat	10/12/2016	3	0	0 (0)	1 (1)	0 (0)	1 (3)	0 (0)	2 (3)	0 (0)	2 (2)	0 (0)

Integrated Solutions



Contributions

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- Re-purposing of ER&SR

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- Literature Review

Lessons Learned

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- Capturing objectives, constraints, and defining them mathematically is difficult. Even if everyone is in agreement at the beginning, once solutions are produced, the goalposts will move.
- Moving goalposts are expected - don't hide them, document them.
- Any problem that involves people will have hidden objectives and constraints.

Summary of Publications

Reid, K.N., Li, J., Swan, J., McCormick, A. and Owusu, G., 2016, December. *Variable Neighbourhood Search: A case study for a highly-constrained workforce scheduling problem.* In Computational Intelligence (SSCI), 2016 IEEE Symposium Series on (pp. 1-6). IEEE.

Reid, K.N., Li, J., Veerapen, N., Swan, J., McCormick, A., Kern, M. and Owusu, G. 2018, September. Shift Scheduling and Employee Rostering: An Evolutionary Ruin & Recreate Solution. In 10th Computer Science and Electronic Engineering Conference (CEEC). IEEE.

Reid, K.N., Li, J., Brownlee, A., Veerapen, N., Swan, J., Kern, M. and Owusu, G. 2019, July. *A Hybrid Metaheuristic Approach to a Real World Employee Scheduling Problem*. In GECCO'19: The Genetic and Evolutionary Computation Conference 2019. ACM, 201

Reid, K.N., 2019, July. Metaheuristics for Solving Real World Employee Rostering and Shift Scheduling Problems. *Thesis*

Thank you for your time.

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