Multi-Modal Employee Routing with Time Windows in an Urban Environment

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ABSTRACT

An urban environment provides a number of challenges and opportunities for organisations faced with the task of scheduling a mobile workforce. Given a mixed set of public and private transportation and a list of scheduling constraints, we seek to find solutions that are optimised with respect to the objectives of CO_2 emissions and time. An optimiser, based on the NSGA-II algorithm, is used to find a range of solutions that offer the multiple options by trading CO_2 emissions against time.

Categories and Subject Descriptors

Applied Computing [**Operations Research**]: Transportation
; Computing Methodologies [**Artificial Intelligence**]: Planning and Scheduling

Keywords

Evolutionary Algorithms; Transportation; Multi-Objective Optimisation

1. INTRODUCTION AND MOTIVATION

Our aim is to explore how public transport links can be introduced within such a mobile workforce scenario and to assess the impact on the objectives of minimising the employee time required to make the visits and the environmental impact of the solution. There are two major considerations when examining modal choice: environmental impact (CO_2 emissions) and travel times.

This paper brings together two strands of work — that of multi-modal Workforce Routing and Scheduling Problems (WRSP) and vehicle routing to optimise emissions. It extends previous work in bringing together the two issues, and treating the problem as multi-objective in terms of meeting constraints, minimising time, and minimising emissions. In addition, it addresses some issues prevalent in the literature with respect to exploiting realistic data by utilising a government sponsored journey planning service in conjunction with an emissions model. A previous investigation into the WRSP incorporating modal choice for transport was carried out in [3] who utilised A two stage approach combining constraint programming and meta heuristics.

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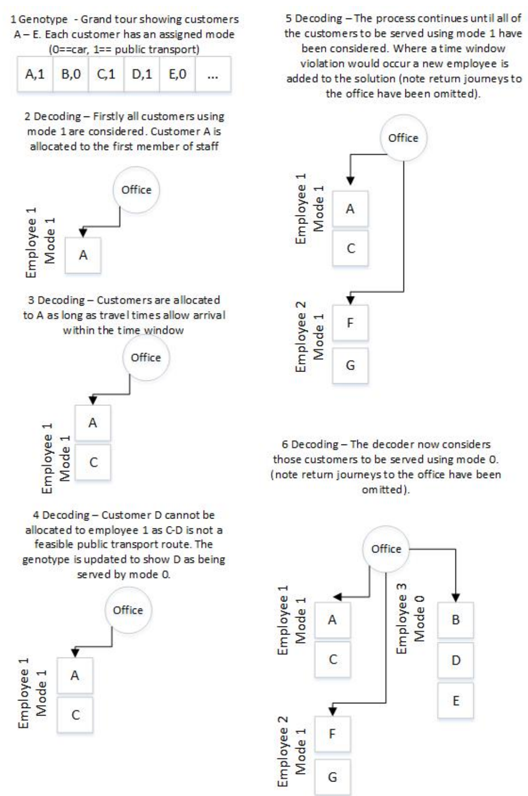


Figure 1: Decoding solutions that incorporate modal choice.

2. METHODOLOGY

The problem instances investigated are based upon 98 addresses within the City of Edinburgh, UK , distributed randomly, each represents a customer who must receive a visit lasting 30 minutes (see table 1. These datasets and the public transport journey options are e available from [7]. Each set used the same 96 addresses and a city center location as the office from which all employees must start/end their day.

The journey data for public transport and emissions is supplied by the Transport Direct bulk journey planning software [6]. Car journeys were modeled using street network data obtained from Open StreetMap, this was subsequently turned into a graph struc-

Set	Visits	Time window length (hrs)	No of time windows
1	96	8	1
2	96	4	2
3	96	2	4
4	96	1	8

Table 1: Description of the problem instances used

		car	
Time Windows	Criterion for best	Time	Emissions
1(8hrs)	Time	3561 (17)	118262.11
1(8hrs)	Emissions	3700 (17)	103043.62
2(4hrs)	Time	3634 (20)	134833.38
2(4hrs)	Emissions	4035 (17)	99359.97
4(2hrs)	Time	3968 (18)	117298.39
4(2hrs)	Emissions	5071 (17)	104721.96
8(1hr)	Time	4149 (23)	136542.22
8(1hr)	Emissions	5920 (18)	109505.08
		pTrans-feasible	
Time Windows	Criterion for best	Time	Emissions
1(8hrs)	Time	3873 (17)	179054.12
1(8hrs)	Emissions	5586 (17)	83413.41
2(4hrs)	Time	3987 (17)	147606.1
2(4hrs)	Emissions	5568 (18)	81841.64
4(2hrs)	Time	4097 (19)	127933.83
4(2hrs)	Emissions	6163 (23)	82065.56
8(1hr)	Time	4863 (23)	137300.15
8(1hr)	Emissions	7820 (24)	86834.02

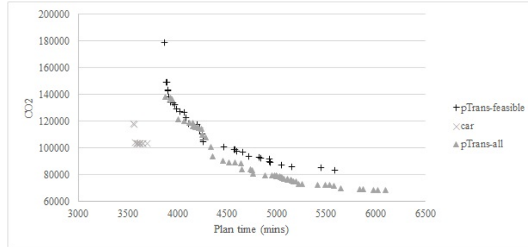
Table 2: A summary of the best solutions found with and without using public transport links. The figures in brackets within the time columns represent the number of employees required within the solution.

ture using the GraphHopper [4] , Emissions for car journeys are obtained by applying emissions factors obtained from the National Atmospheric Emissions Inventory (NAEI) [2].

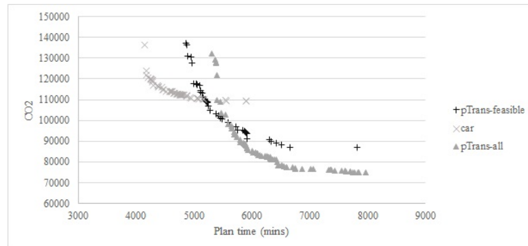
The solver used is based upon the Non-dominated Sorting Genetic Algorithm II (NSGA-II) algorithm [1, 5], with the twin objectives of reducing the predicted emissions generated by the solution and reducing the time required to make the visits. Two objectives are defined firstly to minimise the total employee time required (this is the total time between leaving the office and returning to it for each employee), the second objective is to minimise the estimate CO_2 generated by the planned travel.

3. RESULTS AND CONCLUSIONS

Table 2 shows a summary of the best solutions obtained for each objective within each problem. As might be expected the solutions with the least travel times are obtained using the car, this is particularly pronounced with long time window. As the problem becomes more constrained the solutions take longer and we note that the gap between the fastest solution found using the car and public transport narrows. Based on the evidence presented the NSGA-II based solver capable of producing solutions that make use of public transport links in order to reduce CO_2.



(a) 1 time window (8hrs long)



(b) 8 time windows (1 hr long)

Figure 2: Total solutions produced for the 1 and 8 timeslot problem instances. For completeness results are shown for solutions where all public transport links are included *pTrans-all* **and only those with feasible public transport links (those with less than 3 journey legs** *pTransFeasible*

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4. REFERENCES

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