A clustered-based framework for the home health care planning problem

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Introduction

Real-Life challenges for home care providers in Australia:

- Over the 20 years (1999-2019), the proportion of the population aged 65 years and over increased from 12.3% to 15.9%.
- At 30 June 2020, 42,436 people were using home care services.
- There were 55,483 people who were seeking a home care service at 31 March 2021.
- Home care providers spends a significant amount of money to compensate workers for travel distance, because the current plan of caregivers is inefficient.
- Australia is a multicultural country, and it is not surprising that clients request to be visited by a carer who can speak in their native language
- Clients and workers may have any preferences which must be considered.

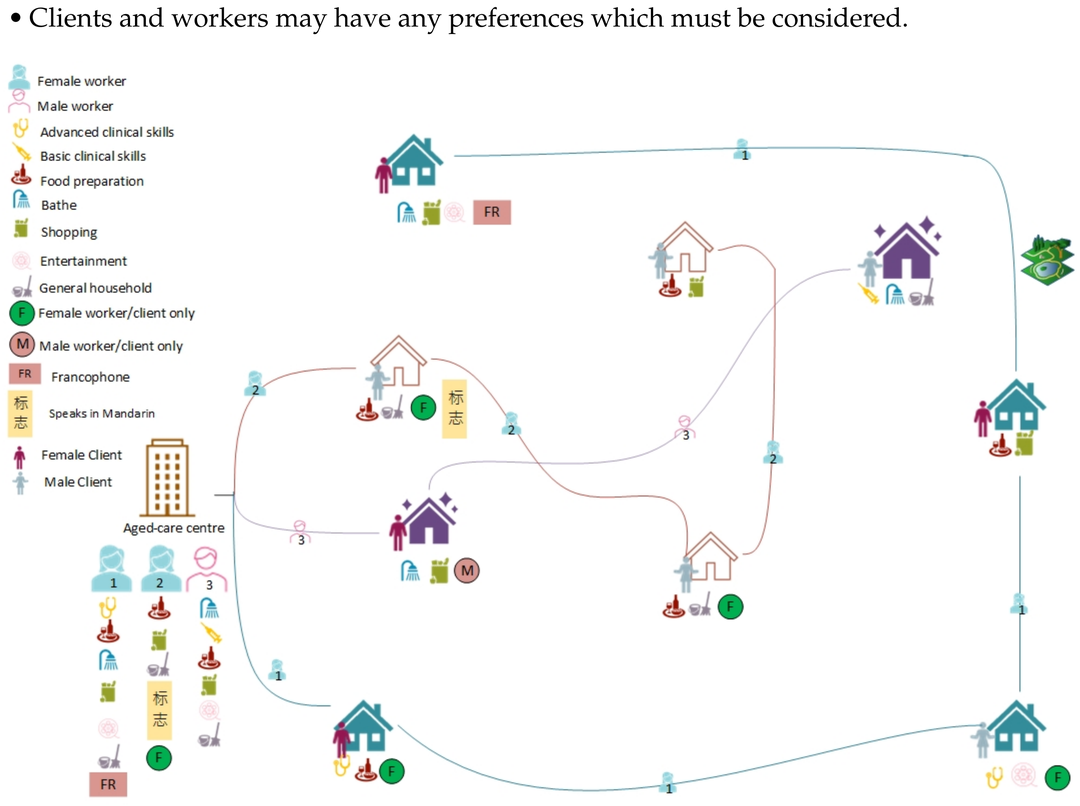


Figure 1: An illustrative example of home care routing and scheduling problem.

Data and Methods

We developed a mathematical model to minimise the total cost of the operation for home care providers with considering real constraints.

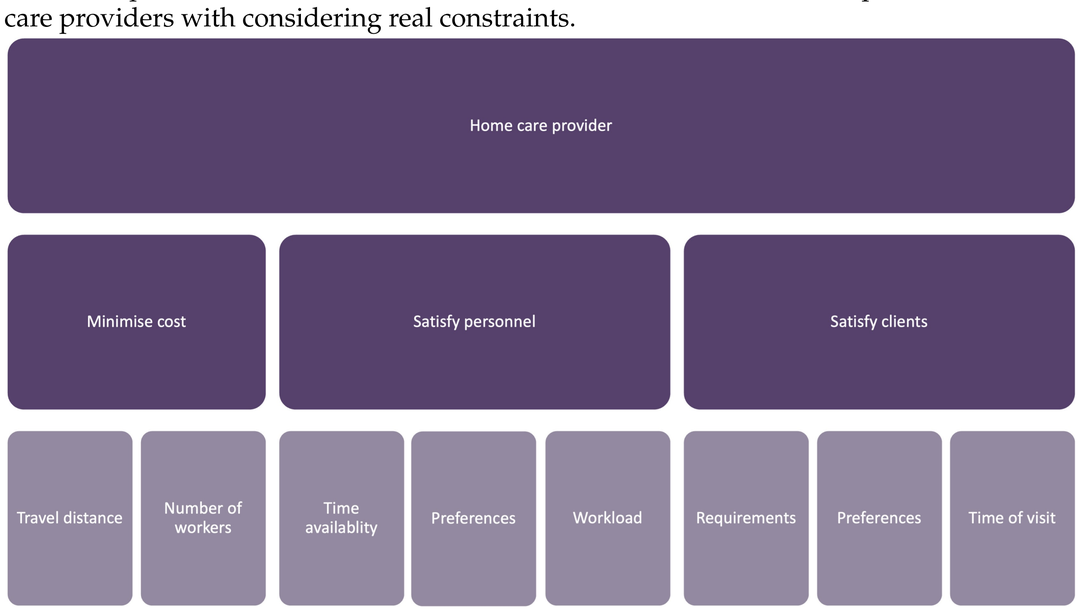


Figure 2: Objective function and practical constraints of the mathematical model

Research challenges for home care planning

- Solving home care planning is computationally expensive.
- Commercial solvers are incapable of generating results for large instances.

Multi-step clustering algorithm We introduced a multi-step clustering algorithm to solve large size instances (500+ clients).

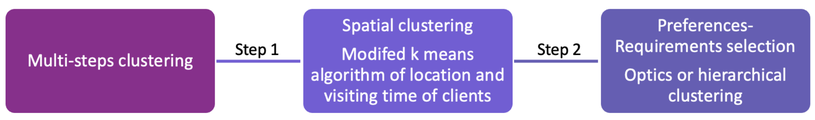


Figure 3: Multi-steps clustering approach

Results

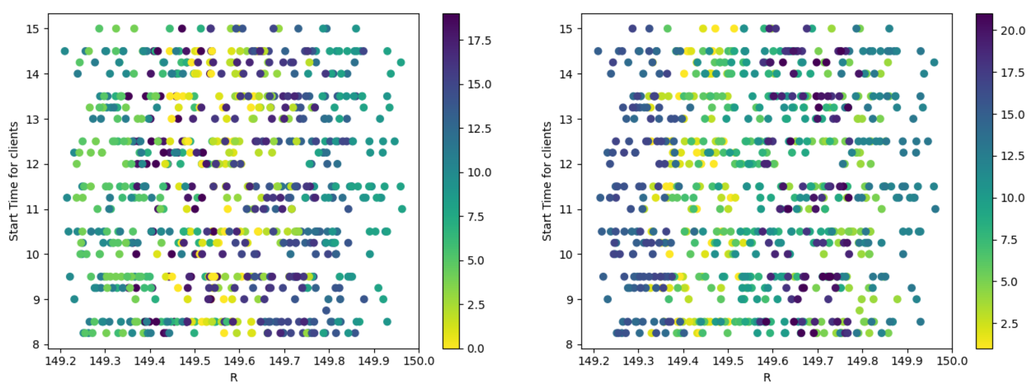
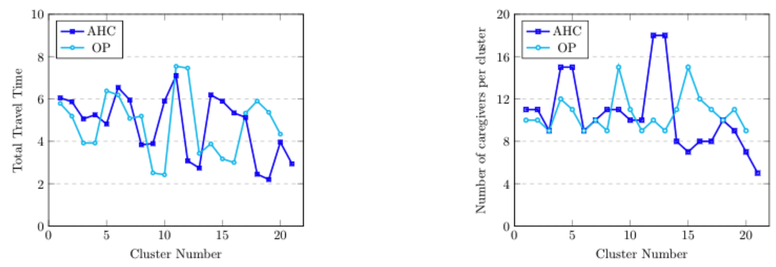


Figure 4: =Final clustering using AHC-MKM (Left) and OP-MKM (Right) algorithms. Different colours used to specify different clusters in each graph.



(a) Total travel time of caregivers for each cluster

(b) Number of caregivers for each cluster

Figure 5: Comparison the performance of OP-MKM and AHC-MKM algorithms in finding the total travel time and number of caregivers for each defined cluster. the total number of OP-MKM and AHC-MKM are 20 and 21 respectively.

Instance	No. Clusters	No.C	Objective	TT (h)	TD (km)
G-800-15-AHC	21	193	Min TT-C	105	4207
G-800-15-OP	20	188	Min TT-C	100	4013
G-800-15-AHC	21	220	Min TT	100	4008
G-800-15-OP	20	213	Min TT	96	3840

Figure 6: Final results of the large-sized benchmark calculated using OP-MKM and AHC-MKM algorithms-small-sized clusters. No. C: Number of used caregivers. OP: OP-MKM, AHC: AHC-MKM. Min TT: Minimising the total travel time of caregivers, Min TT-C: Minimising the total travel time and number of caregivers, TT: Total travel time of caregivers, TD: Total travel distance of caregivers, Time windows is 15 minutes for all instances.

Instance	TW	Objective	No. W	TT (h)	TD (km)
R169-15	15	Min TT	53	6.73	297
R169-30	30	Min TT	53	6.64	266
R169-45	45	Min TT	53	6.49	260
R169-60	60	Min TT	53	6.30	252
R169-75	75	Min TT	53	6.12	245
R169-90	90	Min TT	53	6.09	244
R169-105	105	Min TT	53	6.04	242
R169-120	120	Min TT	53	6.01	240
R169-15	15	Min TT-C	48	11.63	465
R169-30	30	Min TT-C	43	13.85	554

Figure 7: Final solution for 169 clients - Large-sized instance. TW: Time windows of clients per minutes. Min TT: Minimising the total travel time of caregivers, Min TT-C: Minimising the total travel time and number of caregivers, TT: Total travel time of caregivers, TD: Total travel distance of caregivers. Total: The final solution for 800 clients

					Multi-steps clustering			Best known results	
Instance	N	K	C	NV	TD	CT	Gap %	Q	TD
C1_2_1	200	50	200	22	2767.97	509.83	2.34	20	2704.58
C1_2_2	200	50	200	21	2890.18	506.1	2.01	18	2949.46
C1_2_3	200	50	200	20	2831.49	505.01	4.56	18	2708.08
C1_2_4	200	50	200	21	2838.23	528.86	7.32	18	2644.61
C1_2_5	200	50	200	21	2883.51	513.83	6.72	20	2702.05
C1_2_6	200	50	200	22	2990.38	501.51	10.71	20	2701.04
C1_2_7	200	50	200	20	2805.67	506.75	3.87	20	2701.04
C1_2_8	200	50	200	21	2908.65	526.18	5.04	18	2769.19
C1_2_9	200	50	200	22	2804.87	529.51	6.13	18	2642.82
C2_2_1	200	50	700	8	2023.44	543.89	4.76	6	1931.44
C2_2_2	200	50	700	8	1971.16	516.04	5.80	6	1863.16
C2_2_3	200	50	700	8	1883.08	520.51	6.08	6	1775.08
C2_2_4	200	50	700	8	1801.43	509.01	5.75	6	1703.43
C2_2_5	200	50	700	8	1972.85	522.59	5.00	6	1878.85
C2_2_6	200	50	700	8	1951.35	536.02	5.06	6	1857.35
C2_2_7	200	50	700	8	1945.46	505.48	5.19	6	1849.46
C2_2_8	200	50	700	8	1910.53	524.21	4.94	6	1820.53
C2_2_9	200	50	700	8	1936.05	530.78	5.79	6	1830.05
C2_2_10	200	50	700	8	1896.58	515.93	4.98	6	1806.58
R1_2_1	200	50	200	24	4984.11	515.16	4.18	20	4784.11
R1_2_3	200	50	200	22	3565.96	521.8	5.44	18	3381.96
R1_2_4	200	50	200	22	3273.81	503.35	7.06	18	3057.81
R1_2_5	200	50	200	23	4347.86	504.82	5.84	18	4107.86
R1_2_6	200	50	200	22	3795.14	524.39	5.92	18	3583.14
R1_2_7	200	50	200	22	3370.11	505.55	6.98	18	3150.11
R1_2_8	200	50	200	22	3147.99	506.4	6.64	18	2951.99
R1_2_9	200	50	200	22	3964.58	504.22	5.42	18	3760.58
R1_2_10	200	50	200	22	3517.18	525.95	6.54	18	3301.18

Figure 8: The experimental results for Homberger's instances using multi steps clustering approach. N: Number of customers, K: Number of vehicles, C: Capacity of vehicles, NV: Number of occupied vehicles, TD: Travel distance (km), CT: Computational time (s), Gap: Difference of our result with the best published result, Q: Number of occupied vehicles

Summary

1. Results of the model demonstrates 48% improvement compared with the current plan of the home healthcare provider.
2. An incompatibility report for the current schedule of the homecare provider reveals that not all clients and caregivers are being served according to their preferences and requirements while our model suggests a plan comprising all defined constraints.
3. The performance of the clustering framework has been evaluated using Gehring and Homberger's Instances. The gap for almost all instances is less than 10% and the computational time is good enough for operational purposes.

"Caregiving often calls us to lean into love we didn't know possible." - Tia Walker, The Inspired Caregiver: Finding Joy While Caring for Those You Love