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**ENHANCED CELL-BASED ALGORITHM WITH DYNAMIC RADIUS  
IN SOLVING CAPACITATED MULTI-SOURCE WEBER PROBLEM**

**NURHAZWANI BT AHMAD RAZAK**



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Penilai Dalam 2  
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: Dr. Rosshairy Abdul Rahman

Tandatangan :

Penyelia Utama  
(Principal Supervisor)

: Assoc. Prof. Dr. Syariza Abdul Rahman

Tandatangan :

Penyelia Kedua  
(Co-Supervisor)

: Dr. Aida Mauziah Benjamin

Tandatangan :

Dekan Pusat Pengajian  
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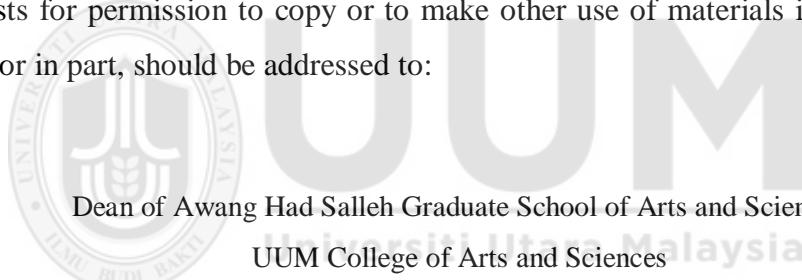
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## Abstrak

Masalah Weber Pelbagai-sumber Berkapasiti (CMSWP) adalah suatu Masalah Peruntukan Lokasi (LAP) yang telah dikaji secara meluas kerana ia boleh diaplikasikan dalam pelbagai konteks. Kaedah pemilihan lokasi sarana secara rawak oleh Kaedah Berasaskan Sel boleh menyebabkan penyelesaian tidak tersaur atau bermutu rendah. Ini disebabkan sel yang tidak mengguntungkan tidak dikecualikan dan mungkin dipilih untuk menempatkan sarana. Akibatnya, kos pengangkutan akan meningkat dan kualiti penyelesaian tidak banyak boleh diperbaiki. Kajian ini mencari lokasi sarana di dalam ruang selanjar untuk memenuhi keperluan pelanggan yang meminimakan kos keseluruhan dengan menggunakan Peningkatan Algoritma Berasaskan-sel (ECBA). Kaedah ini diterbitkan dari kajian terdahulu yang membahagikan taburan pelanggan kepada lokasi sel berpotensi yang lebih kecil. Kajian ini terdiri daripada tiga fasa. Pertama, sel yang mengguntungkan dibina dengan menggunakan ECBA. Kedua, konfigurasi permulaan sarana ditentukan menggunakan radius yang tetap dan dinamik. Ketiga, Masalah Pengangkutan Berselang-seli (ATL) diaplikasikan untuk mencari lokasi baharu. Algoritma tersebut telah diuji ke atas set data yang bersaiz 50, 654 dan 1060 pelanggan. Pengiraan keputusan yang dijana algoritma membuktikan bahawa jumlah jarak adalah lebih baik berbanding keputusan kajian terdahulu. Kajian ini menyediakan pengetahuan yang berguna kepada penyelidik untuk mencari lokasi sarana yang strategik dengan mengambil kira kapasiti sarana.

**Kata Kunci:** Masalah Peruntukan Lokasi, Masalah Pelbagai-sumber Berkapasiti, Peningkatan Algoritma Berasaskan-sel, Radius Dinamik

## Abstract

Capacitated Multi-source Weber Problem (CMSWP) is a type of Location Allocation Problem (LAP) which have been extensively researched because they can be applied in a variety of contexts. Random selection of facility location in a Cell-based approach may cause infeasible or worse solutions. This is due to the unprofitable cells are not excluded and maybe selected for locating facilities. As a result, the total transportation cost increases, and solution quality is not much improved. This research finds the location of facilities in a continuous space to meet the demand of customers which minimize the total cost using Enhanced Cell-based Algorithm (ECBA). This method was derived from previous study that divides the distribution of customers into smaller cells of promising locations. The methodology consists of three phases. First, the profitable cells were constructed by applying ECBA. Second, initial facility configuration was determined using fixed and dynamic radius. Third, Alternating Transportation Problem (ATL) was applied to find a new location. The algorithm was tested on a dataset of three sizes which are 50, 654 and 1060 customers. The computational results of the algorithm prove that the results are superior in terms of total distance compared to the result of previous studies. This study provides useful knowledge to other researchers to find strategic facilities locations by considering their capacities.

**Keywords:** Location Allocation Problem, Capacitated Multi-source Weber Problem, Enhanced Cell-based Algorithm, Dynamic Radius

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## **Glossary of Terms**

Unprofitable	Cell that has least number of customers
Profitable	Cell that has highest number of customers



## List of Abbreviations

LAP	Location Allocation Problem
MWP	Multi-source Weber Problem
CMSWP	Capacitated Multi-source Weber Problem
MCMWP	Multi-source Problem
SCMWP	Single-source      Capacitated      Multi-source Weber Problem
ATL	Cooper's Alternating Transportation Location Problem
GRASP	Greedy Randomized Adaptive Search
GA	Genetic Algorithm
SA	Simulated Annealing
MPSO	Multi-objective Particle Swarm Optimization
NSGA	Non-dominated Sorting Genetic Algorithm
CBA	Cell-based Approach
ECBA	Enhanced Cell-based Algorithm
VNS	Variable Neighbourhood Search
FDR	Furthest Distance Rule
SWP	Single-source Weber Problem
CMWP	Capacitated Multi-facility Weber Problem
CPSO	Continuous Particle Swarm Optimization
DPSO	Discrete Particle Swarm Optimization
ESA	Evolutionary Simulated Annealing
LHA	Langrangean Heuristic Algorithm
EAS	Essential air services
RCL	Restricted Candidate List
DA	Dragonfly Algorithm
GELS	Gravitational Emulation Local Search

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 Location Allocation Problem**

The Location Allocation Problem (LAP) was introduced by Alfred Weber in 1909, where single warehouse and a set of spatially distributed customers were carried out (Abdullah et al., 2008). According to Alizadeh et al., (2015), LAP is defined as locating a set of new facilities in area of interest so that transportation cost can be minimized to satisfy customers demand. In addition, Wen and Iwamura, (2008) states that LAP mainly deals with finding new facility location and it is widely used in real life application. Examples of real life applications are allocation of emergency services (Marianov, 2017), health services (Hamid Afshari, 2014), warehouses (Kazançoğlu, 2009), telecommunication networks (Mosmondor et al., 2006), schools (Menezes & Pizzolato, 2014; Xavier et al., 2020), ambulances (Kaveh & Mesgari, 2019; Liu et al., 2017) and fire stations (Aktaş et al., 2013; Savsar, 2014).

LAP involves five components which are (1) customers, who are assumed to be already present at places or along routes, (2) the new facilities to be located, (3) space in which customers and facilities are located, and (4) metric indicating distances or time between customers and facilities (5) constraints to be satisfied. Since decision in any changes occur in location of facilities is costly and cause huge impact especially on the network's flows and customer satisfaction therefore, lots of research related to this problem was introduced in various classification (Griffin, 2009). Figure 1.1 displays the classes of LAP. The bold lines represent the direction of the classification being explored in this thesis.

## REFERENCES

- Abdullah, T., Zainuddin, Z. M., & Salim, S. (2008). *A Simulated Annealing Approach for Uncapacitated Continuous Location-Allocation Problem with Zone-Dependent Fixed Cost.* 24(1), 67–73.
- Abedi, M., & Gharehchopogh, F. S. (2020). An improved opposition based learning firefly algorithm with dragonfly algorithm for solving continuous optimization problems. *Intelligent Data Analysis*, 24(2), 309–338. <https://doi.org/10.3233/IDA-194485>
- Aktaş, E., Özaydin, Ö., Bozkaya, B., Ülengin, F., & Önsel, Ş. (2013). Optimizing fire station locations for the Istanbul Metropolitan Municipality. *Interfaces*, 43(3), 240–255. <https://doi.org/10.1287/inte.1120.0671>
- Akyüz, M. H., Öncan, T., & Altınel, I. K. (2019). Branch and bound algorithms for solving the multi-commodity capacitated multi-facility Weber problem. *Annals of Operations Research*, 279(1–2), 1–42. <https://doi.org/10.1007/s10479-018-3026-5>
- Alizadeh, M., Mahdavi, I., Mahdavi-Amiri, N., & Shiripour, S. (2015). A capacitated location-allocation problem with stochastic demands using sub-sources: An empirical study. *Applied Soft Computing*, 34, 551–571.
- Altınel, K., Öncan, T., & I, M. H. A. (2014). *Location and allocation based branch and bound algorithms for the capacitated multi-facility Weber problem.* 45–71. <https://doi.org/10.1007/s10479-012-1221-3>
- Aras, N., Altınel, İ. K., & Orbay, M. (2007). New heuristic methods for the capacitated multi-facility Weber problem. *Naval Research Logistics (NRL)*, 54(1), 21–32.
- Aras, N., Orbay, M., & Altınel, I. K. (2008). Efficient heuristics for the rectilinear distance capacitated multi-facility Weber problem. *Journal of the Operational Research Society*, 59(1), 64–79.
- Bischoff, M., Fleischmann, T., & Klamroth, K. (2006). *Bifkl06.Pdf.* 2006, 1–24.
- Brimberg, J., Hansen, P., Mladenović, N., & Taillard, E. D. (2000). Improvements and comparison of heuristics for solving the uncapacitated multisource Weber problem. *Operations Research*, 48(3), 444–460. <https://doi.org/10.1287/opre.48.3.444.12431>

- Brimberg, J., Mladenovic, N., & Salhi, S. (2004). The multi-source Weber problem with constant opening cost. *Journal of the Operational Research Society*, 55(6), 640–646. <https://doi.org/10.1057/palgrave.jors.2601754>
- Brimberg, Jack, Drezner, Z., Mladenović, N., & Salhi, S. (2014). A new local search for continuous location problems. *European Journal of Operational Research*, 232(2), 256–265. <https://doi.org/10.1016/j.ejor.2013.06.022>
- Brimberg, Jack, Hansen, P., Mladenovic, N., & Salhi, S. (2008). A survey of solution methods for the continuous location-allocation problem. *International Journal of Operations Research*, 5(1), 1–12.
- Caserta, M., & Quiñonez Rico, E. (2009). A cross entropy-based metaheuristic algorithm for large-scale capacitated facility location problems. *Journal of the Operational Research Society*, 60(10), 1439–1448.
- Filippi, C., Guastaroba, G., Huerta-Muñoz, D. L., & Speranza, M. G. (2021). A kernel search heuristic for a fair facility location problem. *Computers & Operations Research*, 132, 105292.
- Gamal, M. Danil H., & Salhi, S. (2003). A cellular heuristic for the multisource Weber problem. *Computers and Operations Research*, 30(11), 1609–1624. [https://doi.org/10.1016/S0305-0548\(02\)00095-3](https://doi.org/10.1016/S0305-0548(02)00095-3)
- Gamal, Moh Danil Hendry, & Salhi, S. (2001). Constructive heuristics for the uncapacitated continuous location-allocation problem. *Journal of the Operational Research Society*, 52(7), 821–829.
- Ghaderi, A., Jabalameli, M. S., Barzinpour, F., & Rahmaniani, R. (2012). An Efficient Hybrid Particle Swarm Optimization Algorithm for Solving the Uncapacitated Continuous Location-Allocation Problem. *Networks and Spatial Economics*, 12(3), 421–439. <https://doi.org/10.1007/s11067-011-9162-y>
- Ghezavati, V. (2009). A Robust Approach to Location-Allocation Problem under Uncertainty. *Journal of Uncertain Systems*, 3(2), 131–136. <http://www.worldacademicunion.com/journal/jus/jusVol03No2paper06.pdf>
- Griffin, C. E. (2009). What you should know about. *Compendium: Continuing Education For Veterinarians*, 31(11), 535–536. <https://doi.org/10.1097/00152193-198712000-00022>
- Grubesic, T. H., & Wei, F. (2012). Evaluating the efficiency of the Essential Air Service program in the United States. *Transportation Research Part A: Policy and Practice*, 46(10), 1562–1573. <https://doi.org/10.1016/j.tra.2012.08.004>

- Guner, A. R., & Sevkli, M. (2008). A Discrete Particle Swarm Optimization Algorithm for Uncapacitated Facility Location Problem. *Journal of Artificial Evolution and Applications*, 2008, 1–9. <https://doi.org/10.1155/2008/861512>
- Hamid Afshari, Q. P. (2014). Challenges and Solutions for Location of Healthcare Facilities. *Industrial Engineering & Management*, 03(02). <https://doi.org/10.4172/2169-0316.1000127>
- Hosseinienezhad, S. J., Salhi, S., & Jabalameli, M. S. (2015). A Cross Entropy-based heuristic for the capacitated multi-source Weber problem with facility fixed cost. *Computers and Industrial Engineering*, 83, 151–158. <https://doi.org/10.1016/j.cie.2015.01.013>
- Irawan, C. A., Luis, M., Salhi, S., & Imran, A. (2019). The incorporation of fixed cost and multilevel capacities into the discrete and continuous single source capacitated facility location problem. *Annals of Operations Research*, 275(2), 367–392. <https://doi.org/10.1007/s10479-018-3014-9>
- Kaveh, M., & Mesgari, M. S. (2019). Improved biogeography-based optimization using migration process adjustment: An approach for location-allocation of ambulances. *Computers and Industrial Engineering*, 135(June 2019), 800–813. <https://doi.org/10.1016/j.cie.2019.06.058>
- Klose, A., & Drexl, A. (2005). Facility location models for distribution system design. *European Journal of Operational Research*, 162(1), 4–29. <https://doi.org/10.1016/j.ejor.2003.10.031>
- Kucukdeniz, T., & Esnaf, S. (2018). Hybrid revised weighted fuzzy c-means clustering with Nelder-Mead simplex algorithm for generalized multisource Weber problem. *Journal of Enterprise Information Management*, 31(6), 908–924. <https://doi.org/10.1108/JEIM-01-2018-0002>
- Lara, C. L., Trespalacios, F., & Grossmann, I. E. (2018). Global optimization algorithm for capacitated multi-facility continuous location-allocation problems. *Journal of Global Optimization*, 71(4), 871–889. <https://doi.org/10.1007/s10898-018-0621-6>
- Lin, Y. H., Batta, R., Rogerson, P. A., Blatt, A., & Flanigan, M. (2012). Location of temporary depots to facilitate relief operations after an earthquake. *Socio-Economic Planning Sciences*, 46(2), 112–123. <https://doi.org/10.1016/j.seps.2012.01.001>
- Liu, M., Yang, D., & Hao, F. (2017). Optimization for the Locations of Ambulances under Two-Stage Life Rescue in the Emergency Medical Service: A Case Study

in Shanghai, China. *Mathematical Problems in Engineering*, 2017. <https://doi.org/10.1155/2017/1830480>

Luis, M., Ramli, M. F., & Saputra, R. S. (2015). Efficient GRASP based heuristics for the capacitated continuous location-allocation problem. *AIP Conference Proceedings*, 1660(May 2014). <https://doi.org/10.1063/1.4915703>

Luis, M., Salhi, S., & Nagy, G. (2009). Region-rejection based heuristics for the capacitated multi-source Weber problem. *Computers and Operations Research*, 36(6), 2007–2017. <https://doi.org/10.1016/j.cor.2008.06.012>

Luis, M., Salhi, S., & Nagy, G. (2011). A guided reactive GRASP for the capacitated multi-source Weber problem. *Computers and Operations Research*, 38(7), 1014–1024. <https://doi.org/10.1016/j.cor.2010.10.015>

Luis, M., Salhi, S., & Nagy, G. (2015). A constructive method and a guided hybrid GRASP for the capacitated multi-source weber problem in the presence of fixed cost. *Journal of Algorithms and Computational Technology*, 9(2), 215–232. <https://doi.org/10.1260/1748-3018.9.2.215>

Manzour, H., Torabi, A., & Pishvaee, M. S. (2013). New heuristic methods for the single-source capacitated multi facility Weber problem. *International Journal of Advanced Manufacturing Technology*, 69(5–8), 1569–1579. <https://doi.org/10.1007/s00170-013-5114-7>

Marianov, V. (2017). Location models for emergency service applications. In *Leading Developments from INFORMS Communities* (pp. 237–262). INFORMS.

Menezes, R. C., & Pizzolato, N. D. (2014). Locating public schools in fast expanding areas: Application of the capacitated p-median and maximal covering location models. *Pesquisa Operacional*, 34(2), 301–317. <https://doi.org/10.1590/0101-7438.2014.034.02.0301>

Meyer, T., Ernst, A. T., & Krishnamoorthy, M. (2009). A 2-phase algorithm for solving the single allocation p-hub center problem. *Computers and Operations Research*, 36(12), 3143–3151. <https://doi.org/10.1016/j.cor.2008.07.011>

Mirjalili, S. (2016). SCA: A Sine Cosine Algorithm for solving optimization problems. *Knowledge-Based Systems*, 96, 120–133. <https://doi.org/10.1016/j.knosys.2015.12.022>

Mohammadi, N., Malek, M. R., & Alesheikh, A. A. (2010). A new ga based solution for capacitated multi source weber problem. *International Journal of*

*Computational Intelligence Systems*, 3(5), 514–521.  
<https://doi.org/10.1080/18756891.2010.9727718>

Mohammadpour, T., Bidgoli, A. M., Enayatifar, R., & Javadi, H. H. S. (2019). Efficient clustering in collaborative filtering recommender system: Hybrid method based on genetic algorithm and gravitational emulation local search algorithm. *Genomics*, 111(6), 1902–1912.  
<https://doi.org/10.1016/j.ygeno.2019.01.001>

Mokhtarzadeh, M., Tavakkoli-Moghaddam, R., Triki, C., & Rahimi, Y. (2021). A hybrid of clustering and meta-heuristic algorithms to solve a p-mobile hub location-allocation problem with the depreciation cost of hub facilities. *Engineering Applications of Artificial Intelligence*, 98(April 2020), 104121.  
<https://doi.org/10.1016/j.engappai.2020.104121>

Mosmondor, M., Skorin-kapov, L., Filjar, R., & Matijasevic, M. (2006). *Conveying and Handling Location Information in the IP Multimedia Subsystem*. 2(4), 313–321.

Mousavi, S. M., Niaki, S. T. A., Mehdizadeh, E., & Tavarroth, M. R. (2013). The capacitated multi-facility location-allocation problem with probabilistic customer location and demand: Two hybrid meta-heuristic algorithms. *International Journal of Systems Science*, 44(10), 1897–1912.  
<https://doi.org/10.1080/00207721.2012.670301>

Oncan, T. (2009). Logistik Management. *Logistik Management*, 229–230.  
<https://doi.org/10.1007/978-3-7908-2362-2>

Öncan, T. (2013). Heuristics for the single source capacitated multi-facility Weber problem. *Computers and Industrial Engineering*, 64(4), 959–971.  
<https://doi.org/10.1016/j.cie.2013.01.005>

Pereira, Marcos A., Coelho, L. C., Lorena, L. A. N., & De Souza, L. C. (2015). A hybrid method for the Probabilistic Maximal Covering Location-Allocation Problem. *Computers and Operations Research*, 57, 51–59.  
<https://doi.org/10.1016/j.cor.2014.12.001>

Pereira, Marcos Antonio, Senne, E. L. F., & Lorena, L. A. N. (2010). A decomposition heuristic for the maximal covering location problem. *Advances in Operations Research*, 2010. <https://doi.org/10.1155/2010/120756>

Phanden, R. K., Jain, A., & Verma, R. (2012). A genetic algorithm-based approach for job shop scheduling. *Journal of Manufacturing Technology Management*, 23(7), 937–946. <https://doi.org/10.1108/17410381211267745>

Prof, A., & Kazançoğlu, Y. (2009). *the Location Problem of a Plant and a Warehouse By an Expanded Linear*. 9(1), 29–42.

Raeisi Dehkordi, A. (2019). The Optimal Solution Set of the Multi-source Weber Problem. *Bulletin of the Iranian Mathematical Society*, 45(2), 495–514. <https://doi.org/10.1007/s41980-018-0145-3>

Rahmaniani, R., Saidi-Mehrabad, M., & Ashouri, H. (2013). Robust capacitated facility location problem: Optimization model and solution algorithms. *Journal of Uncertain Systems*, 7(1), 22–35.

Sarkar, A., Batta, R., & Nagi, R. (2004). Commentary on facility location in the presence of congested regions with the rectilinear distance metric. *Socio-Economic Planning Sciences*, 38(4), 291–306. [https://doi.org/10.1016/S0038-0121\(03\)00025-9](https://doi.org/10.1016/S0038-0121(03)00025-9)

Savsar, M. (2014). Fire station location analysis in a metropolitan area. *International Journal of Industrial and Systems Engineering*, 16(3), 365–381.

Sevkli, M., & Guner, A. R. (2006). A continuous particle swarm optimization algorithm for uncapacitated facility location problem. *Lecture Notes in Computer Science (Including Subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, 4150 LNCS, 316–323. [https://doi.org/10.1007/11839088\\_28](https://doi.org/10.1007/11839088_28)

Shifa, N., Ain, F., Abdul-rahman, S., Luis, M., & Benjamin, A. M. (2021). *MULTI-FACILITY WEBER PROBLEM WITH CONTINUOUS FIXED COSTS*. 55, 2055–2068.

Singhtaun, C., & Charnsethikul, P. (2008). Efficient heuristics for single-source capacitated multifacility weber problems. *38th International Conference on Computers and Industrial Engineering 2008*, 1(October), 35–40.

Sirovich, A. J. E. M. L., Keener, H. J., Laubenbacher, J. K. R., Mielke, B. J. M. A., Sreenivasan, C. S. P. K. R. S., & Stuart, A. S. A. (2011). *Volume 175*.

Skakov, E. S., & Malysh, V. N. (2018). Parameter meta-optimization of metaheuristics of solving specific NP-hard facility location problem. *Journal of Physics: Conference Series*, 973(1). <https://doi.org/10.1088/1742-6596/973/1/012063>

Tong, D., Ren, F., & Mack, J. (2012). Locating farmers' markets with an incorporation of spatio-temporal variation. *Socio-Economic Planning Sciences*, 46(2), 149–156. <https://doi.org/10.1016/j.seps.2011.07.002>

- Wen, M., & Iwamura, K. (2008). Facility location-allocation problem in random fuzzy environment: Using  $(\alpha,\beta)$  -cost minimization model under the Hurewicz criterion. *Computers and Mathematics with Applications*, 55(4), 704–713. <https://doi.org/10.1016/j.camwa.2007.03.026>
- Wu, L. Y., Zhang, X. S., & Zhang, J. L. (2006). Capacitated facility location problem with general setup cost. *Computers and Operations Research*, 33(5), 1226–1241. <https://doi.org/10.1016/j.cor.2004.09.012>
- Xavier, C. M., Costa, M. G. F., & Costa Filho, C. F. F. (2020). Combining facility-location approaches for public schools expansion. *IEEE Access*, 8, 24229–24241.
- Zainuddin, Z. M., & Salhi, S. (2007). A perturbation-based heuristic for the capacitated multisource Weber problem. *European Journal of Operational Research*, 179(3), 1194–1207. <https://doi.org/10.1016/j.ejor.2005.09.050>
- Zeinal Hamadani, A., Abouei Ardakan, M., Rezvan, T., & Honarmandian, M. M. (2013). Location-allocation problem for intra-transportation system in a big company by using meta-heuristic algorithm. *Socio-Economic Planning Sciences*, 47(4), 309–317. <https://doi.org/10.1016/j.seps.2013.03.001>
- Zhou, J., & Liu, B. (2003). New stochastic models for capacitated location-allocation problem. *Computers & Industrial Engineering*, 45(1), 111–125.