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Survey

Hierarchical facility location problem: Models, classifications, techniques, and applications

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ABSTRACT

The primary objective in a typical hierarchical facility location problem is to determine the location of facilities in a multi-level network in a way to serve the customers at the lowest level of hierarchy both efficiently (cost minimization objective) and effectively (service availability maximization objective). This paper presents a comprehensive review of over 40 years of hierarchical facility location modeling efforts. Published models are classified based on multiple characteristics including the type of flow pattern, service availability, spatial configuration, objective function, coverage, network levels, time element, parameters, facilities, capacity, and real world application. A second classification is also presented on the basis of solution methods adopted to solve various hierarchical facility location problems. The paper finally identifies the gaps in the current literature and suggests directions for future modeling efforts.

1. Introduction

A hierarchical facility location problem (HFLP) aims to determine the location of facilities in a way that facilities in higher level can serve lower-level facilities both efficiently (financial objective) and effectively (accessibility objective). For a health-care system, for instance, the hierarchical facility network may consist of three levels including local clinics, hospitals and medical centers. The lowest-level facility in this case is the local clinic providing direct services to incoming patients. A hospital at the middle level provides services to local clinics and undertakes out-patient surgeries. The medical center at the highest hierarchy provides services to the hospital and responds to in-patient cases. Other examples of HFLP may include solid waste management networks, postal delivery services, education systems, banking systems, and production–distribution systems (Daskin, 1995; Narula, 1986). Facilities located at each level are not separate entities and hence the location of each facility must be determined in accordance with its impact on the overall system.

Perhaps the earliest review of HFLPs dates back to the work of Narula (1986) presenting a classification of hierarchical *p*-median problems. Church and Eaton (1987) review HFLPs with maximum covering objectives. After Daskin (1995) who developed a framework for HFLPs in a chapter of his book, several studies have aimed to extend his model (see for instance Ratick, Osleeb, & Hozumi, 2009). In a most recent work, Şahin and Süral (2007) represented a classification and survey of HFLP studies published until 2004. Contributions of our review and analysis to the previous works in this context include the following:

- An increasing number of studies in different disciplines are adopting the concept of HFLP modeling and hence more articles are available for review and classification purpose. To the best of our knowledge, the most recent review paper in this area is the work of Şahin and Süral (2007) surveying about 100 articles published before early 2004. Our paper presents a creative review of over 40 years of HFLP modeling efforts including those published after 2004 (standing for over 30% of all publications to date).
- Most review papers in the field place emphasis on classifying HFLP modeling efforts without proper investigation of the solution approaches used and the type and nature of case studies investigated. We address this gap in the current paper.
- We consider a broad range of characteristics for classification and analysis of the existing literature. Such characteristics as the number of facilities and capacity limits have never been used in the past for classification/analysis purposes.

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- Practical and managerial insights as well as directions for future research in the field are well thought and structured in this paper.

2. Review scope

SCOPUS was utilized to search for the related hierarchical facility location models published between 1978 and 2012. Using keywords "Hierarchical" AND "Location" AND "Facility", 121 journal articles were found, a primary classification of which is shown in Table 1. Our investigation shows that the articles found under this set of keywords are the most relevant works to the research area of HFLP modeling. For instance, exclusion of the keyword "Facility" results in a substantial increase in the number of articles found to over 4000 articles, majority of which were found to be irrelevant to the research area of HFLP modeling. Table 1 shows the increasing rate of published articles in the field, more noticeably after 2003 (numbers in parentheses represent the number of papers appeared in our search results). This well demonstrates the recognized significance of research in the area of HFLP modeling and optimization. The inclusion of conference papers and books could obviously result in a larger number of records.

3. HFLP applications and case studies

The primary application of HFLP modeling may locate in one of the following areas/disciplines (refer to Table 2):

- *Health care system* has been the most published form of HFLPs. Health care systems usually consist of hierarchically located facilities, like domestic infirmaries, equipped clinics, and medical stations such as hospitals with various specialties and service availabilities.
- *Solid waste management (disposal) system* has been reported in the literature as another application of HFLP modeling. Facilities in a typical solid waste management system include transfer stations, disposal centers, and landfill stations.
- A typical *production–distribution system* contains three levels of facilities including factories, warehouses and retail outlets.

Table 1
Summary of SCOPUS's report using keywords: "Hierarchical" AND "Location" AND "Facility".

Publisher	Author	Publication year	Subject area
European Journal of Operational Research(17)	Galvao, R.D.(6)	2012(4)	Social Sciences(45)
Computers and Operations Research(6)	Boffey, B.(5)	2011(11)	Decision Sciences(45)
Computers and Industrial Engineering(5)	Hodgson, M.J.(3)	2010(15)	Mathematics(38)
Annals of Operations Research(4)	Marianov, V.(3)	2009(10)	Engineering(34)
Social Science and Medicine(4)	Serra, D.(3)	2008(6)	Computer Science(30)
Location Science(3)	Pirkul, H.(2)	2007(8)	Medicine(12)
Papers in Regional Science(2)	Narula, S.C.(2)	2006(5)	Environmental Science(10)
Transportation Science(2)	Espejo, L.G.A.(2)	2005(6)	Business, Management and Accounting(9)
Socio Economic Planning Sciences(2)	Lin, A.Y.S.(2)	2004(7)	Earth and Planetary Sciences(9)
International Journal of Advanced Manufacturing Technology(2)	Yates, D.(2)	2003(6)	Economics, Econometrics and Finance(7)
Journal of the Operational Research Society(2)	Lin, Y.T.(2)	2002(2)	Psychology(3)
SIAM Journal on Computing(2)	Chan, Y.(2)	2001(2)	Agricultural and Biological Sciences(2)
Microprocessors and Microsystems(1)	Paixao, J.(1)	1999(3)	Energy(1)
Mathematical and Computer Modeling(1)	Palot, M.(1)	1998(2)	Immunology and Microbiology(1)
Journal of Uncertain Systems(1)	Pannesi, R.(1)	1997(5)	Chemistry(1)
Journal of Transportation Engineering(1)	Papadimitriou, E.(1)	1996(2)	Chemical Engineering(1)
Journal of Transport Geography(1)	Papiernik, E.(1)	1994(2)	Neuroscience(1)
Journal of Technology(1)	Partovi, F.Y.(1)	1993(1)	Nursing(1)
Journal of Quality(1)	Pastor, J.T.(1)	1992(5)	Biochemistry, Genetics and Molecular Biology(1)
Journal of Parallel and Distributed Computing(1)	Pahlavani, A.(1)	1991(1)	Veterinary(1)
Journal of Operations Management(1)	Pegler, S.(1)	1990(3)	
Journal of Natural Disasters(1)	Peleg, D.(1)	1989(2)	
Journal of Management in Medicine(1)	Osleeb, J.P.(1)	1988(3)	
Journal of Environmental Science and Health Part A Toxic Hazardous Substances and Environmental Engineering(1)	Salhi, S.(1)	1987(3)	
Journal of Environmental Management(1)	Sahin, G.(1)	1986(2)	
Water Science and Engineering(1)	Saha, S.(1)	1985(2)	
Urban Studies(1)	Romero, A.J.(1)	1984(1)	
Turkish Journal of Electrical Engineering and Computer Sciences(1)	ReVelle, C.(1)	1983(1)	
Transportation Research Part B Methodological(1)	Ratick, S.J.(1)	1978(1)	
Transportation Planning and Technology(1)	Rathore, S.S.(1)		
Systems and Computers in Japan(1)	Rashidinejad, M.(1)		
Spectroscopy Letters(1)	Rao, S.(1)		
Scientia Iranica(1)	Rao, S.(1)		
Sao Paulo Medical Journal(1)	Rajaraman, R.(1)		
Revista De Saude Publica(1)	Raggi, L.A.(1)		
Reports of the Electrical Communication Laboratory(1)	Quidu, F.(1)		
Rail International(1)	Potts, C.N.(1)		
Quality and Reliability Engineering International(1)	Pontes da Silva, G.A.(1)		
Preventive Veterinary Medicine(1)	Poh, K.L.(1)		
Papers of the Regional Science Association(1)	Plasil, J.(1)		