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A Systematic Classification of Applications of Location-Allocation Models

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Abstract

This paper presents a systematic classification of formally published applications of location allocation-modelling. Its body is composed of two parts. First, a table of classification in which each paper is classified by 1). sector (public, private or academic) and subclassified by type (emergency, fire, etc.); 2). formal model type (p-median, etc.); 3). the nature of the real world application. Comments on features of special interest are also indicated in the table. Second, a bibliographic section which contains the full reference to the entries in the table of classification. Before this, the meat of the paper, however, we briefly discuss the reasons for the list, the limits on candidates to be considered, the classification system and the difficulty of forcing such heterogeneous literature into a rigid structure.

1. INTRODUCTION

The history of studies in the theory of location begins with the work of Von Thünen (1826) and proceeds, with increasing complexity, with the work of Launhardt (1882), Weber (1909), Christaller (1933), and Lösch (1940). Studies directly involving numerical analysis largely had to await the advent of the digital computer. Miehle (1958), Kuhn and Kuenne (1962), Cooper (1963), Maranzana (1963), Hakimi (1964, 1965) and Teitz and Bart (1964) mark the beginning of its rapid development by practitioners in fields as diverse as management science, operations research, geography, regional science, forestry, electronics, transportation, computer science, marketing, military science and water engineering.

For the ISOLDE VI meeting in 1993 we compiled a review of location-allocation applications (Hodgson *et al.*, 1993). In the intervening three years we have found a number of references which should have been included in that survey. More important than the completeness of the earlier work is, however, the fact that a number of new articles have been published, which by their subject matter, even in their extreme diversity, indicate explicitly the directions in which practical work in the field is moving. For this last reason we thought that it appropriate to present an updated version of the 1993 work in this *JORBEL* special issue on applications.

There also exists a certain tension in the field of location-allocation concerning the relative importance of application oriented studies in location-allocation. Although the lines are not clear cut -crossovers are the rule rather than the exception- two groups can be identified. A number of workers (group A) who most usually utilize random or otherwise contrived examples (usually small) to test and to demonstrate aspects of solution techniques or of the problem. They calculate such elements as worst case complexity, tighter upper (lower) bounds, prove NP-completeness of a problem, etc. These persons can point to the generality of their results. Another group (group B) most often base their studies upon real world data either self gathered or from public sources. Their results have at least the potential of offering real advice to decision makers concerning the advantages or disadvantages of specific actions in a specific case. Members of group A point out that the very specificity of the work of members of group B limits its utility. Members of group B point out that the generality of the work of group A ignores the spatial structure inherent in the real world and that this seriously limits the true utility of their work. It is our experience that there are significant differences in the effectiveness of models and in the efficiency of the solution methods between the "real" and "random/contrived" world -- the models usually work better with real world data with its concomitant structure. This was forcefully brought to our attention by the diametrical difference in results between a study with a hypothetical random network (Hodgson and Rosing, 1992) to those obtained employing the same model and method on a real world data set (Hodgson *et al.*, in press).

Work from group B surely suffers a number of handicaps. First, the (often very large amount of) work in collecting and validating their data sets. Second, the huge size that real world data sets entail requires large amounts of computing power and the most sophisticated of established solution methods. Third, the specificity of the example will frequently be seen as limiting to its publishability, even if confidentiality allows it. One of the current authors has had the indignity of being told, by the editor of a major journal concerning an applied study in Edmonton, that the paper might be more appropriate to a journal concerned with Edmonton. The other author as had, twice, (once dealing with a local authority about ambulance systems and once dealing with a non-governmental agency about locations for dialysis units) the experience of having permission to use data or publish results retracted when the results of a completed study were politically unacceptable to the "cooperating" entity.

We feel that both approaches have their unique contributions to make in method and model development and verification. What we would advocate is more intercourse between groups A and B to their mutual advantage. We hope that this compilation of applications, published by group B, will provide additional impetus to this end.

2. THE LIMITS

The wide range of available material means that specific limits must be imposed upon candidates for inclusion in order to maintain the specific focus and thus maximize the utility of the work. First, we limit ourselves to strict location-allocation approaches to multi-facility systems which use optimal methods or heuristics to find locations and allocate demand. This means the exclusion of analog systems such as Kennelly's (1954) Varignon frame for the plant location problem; accessibility studies such as Huff's (1966) study of retail locations; statistical studies such as Anderson's (1971) search for a noxious facility site; and spatial interaction theory such as Coelho and Wilson's (1976) probabilistic allocation work. Second, much application work is done on private contract for private or public sponsors who consider the results to be of a confidential nature, and as a result, these studies are never published in the public domain. We limit ourselves to published, widely available studies, such as those which would be available in a good academic library or by interlibrary loan, since an extended list of unavailable fugitive, confidential reports or unavailable "grey publications" would be frustrating at best.

While strict when judging eligibility of subject matter we are inclusive in determination of what is an application. Many studies are included which are demonstrations of the applicability of a particular model to a real world problem. Here our justification is that they indicate the manner of connection between the real world and the model in question. Additionally, such demonstrations are a vehicle often employed by authors who are prevented from more detailed publication by the confidentiality imposed upon them. This at least allows them to indicate the more innovative aspects involved in unpublishable work.

The literature search has now produced some 200 studies which meet our criteria. The studies are classified by application, for each the model structure is indicated, the nature of the application and brief comments on salient or unusual details. Reference to a comprehensive description of discrete models, such as that of Daskin (1995), may be appropriate. We apologize to authors whose work is not included or who feel we ignored significant aspects or misinterpreted the significance of their contribution. Undoubtedly, significant omissions remain; we welcome references (preferably reprints or photocopies) to call them to our attention. The same applies to new work in applications as it comes out: who knows maybe we will do this again (at great risk to health in dark, dank, dirty, and dingy library basements).

3. THE CLASSIFICATION

Clarification of abbreviations used in the Table:

b&b	- branch and bound
cap.	- capacitated
EMS	- Emergency Medical Services
FLEET	- Facility-Location Equipment-Emplacement Technique
g-p	- goal programming
GIS	- Geographic Information System
JiT	- Just in Time
LA	- Location Allocation
LAN	- Local Area Network
LSCP	- Location Set Covering Problem
max	- maximum
MCLP	- Maximum Covering Location Problem
min	- minimum
MIP	- Mixed Integer Programming
m-o	- multi-objective
PHC	- Primary Health Care
pop.	- population
sim.	- simulation
TEAM	- Tandem Equipment Allocation Model
var.	- variables

Name and Date	Model Structure	Real World Application	Comments
PUBLIC FACILITIES			
EMERGENCY			
Ambulance			
Berlin, Liebman 74	modified set covering	EMS	uses simulation to allocate demands
Berlin *et al.* 76	p-median	EMS ambulance/hospital location	considers journey to accident & onward to hospital
Chaiken 78	review article	EMS	reviews actual use of models in USA cities
Charnes, Storbeck 80	hierarchical covering	EMS	uses g-p
Daberkow 77	min response time with fixed costs	rural N. California EMS	strong detail on data collection
Daberkow, King 77	min response time with fixed costs	rural N. California EMS	strong detail on data collection
Daskin, Stern 81	hierarchical objectives: set covering, multiple coverage	Austin, Texas EMS	hierarchical objectives
Daskin 82	expected covering model	Austin, Texas EMS	simple probability approach avoids complexity of queueing
Eaton *et al.* 85	review of study	Austin, Texas EMS	
Fitzsimmons 73a	min response time	Los Angeles, Cal. EMS	allocates ambulances to fire stations
Fitzsimmons 73b	min response time	Los Angeles, Cal. EMS	response time depends on number of ambulances busy
Fujiwara *et.al.* 87	max expected cover	Bangkok, Thailand EMS	final solution via simulation
Fujiwara *et al.* 88	probabilistic cover & expected cover	Bangkok, Thailand EMS	validated by simulation
Goldberg, *et al.* 90	sim. to validate location sets	Tucson, Arizona EMS	real world implementation
Goldberg, Paz 91	covering with queueing	Tucson, Arizona EMS	compares heuristics
Hall 72	queueing assigns vehicles to areas	Detroit, MC EMS	dual function model locates both EMS & police
Hogan, ReVelle 83	coverage with backup	EMS	introduces backup coverage
Larson 74	m-o with queueing	Urban emergency, police, fire, ambulance	early use of m-o approach & queueing
O'Kelly, Storbeck 84	hierarchical	EMS	uses interaction model for probabilistic allocation

Name and Date	Model Structure	Real World Application	Comments
Pirkul, Schilling 88	multiple objective	anonymous USA city EMS	considers backup service & capacities based on workload control
Repede, Bernardo 94	max expected coverage, time var.	EMS Louisville, Kentucky	response time improved by 36%
ReVelle 87	review article	EMS	excellent review of objective functions for EMS LA models.
ReVelle, Hogan 89	expected cover with backup	Baltimore EMS	introduces maximum available cover
ReVelle *et al.* 77	review article	EMS	layman's review of LA approaches to EMS
Sasaki 76	four models	Hiroshima ambulances	
Swoveland *et al.* 73	p-median	Vancouver, British Columbia EMS	simulates stochastic calls, heuristic b&b
Toregas *et al.* 71	set covering	EMS	early LA application
Volz 71	minimize average response time	rural ambulances	interesting average response time function
Fire			
Bianchi, Church 90	FLEET & max expected coverage	Austin, Texas fire stations & equipment	locates stations & allocates equipment
Hodgson, Newstead 78	p-median, max distance constrained	Alberta, Canada air tankers for forest fires	
Hodgson, Newstead 83	several LA models	Alberta, Canada air tankers for forest fires	compares LA models
Hogg 68	p-median	Bristol fire stations	
Ignall *et al.* 75	project description	NYC fire stations	description of RAND project queueing considerations
Kolesar, Walker 74	hierarchical	NYC fire stations	considers relocation
Mirchandani, Reilly 87	maximize response time utility function	Albany, New York, fire fighting units	good review of modelling problems
Plane, Hendrick 77	hierarch. objective min # stations & min # new stations	Denver fire stations	model validation
Richard *et al.* 90	p-median, min max, set covering	fire stations in rural area	compares several objectives, rare application of p-centre model
Schilling *et al.* 79	coverage models	Baltimore fire protection system TEAM/FLEET	chooses locations & distributes specialized equipment
Schilling *et al.* 80	m-o	Baltimore fire protection system	good discussion of m-o models for LA

Name and Date	Model Structure	Real World Application	Comments
Schreuder 81	set covering	fire stations in Rotterdam, Neth.	
Schultz, Risinger 81	p-median	fire services in Florida	
Van Loon 1977	LSCP	fire stations in Rotterdam, Neth.	Locates stations, assigns sufficient equipment to cover fire risk
Walker 74	set covering	fire equipment in NYC	
SALUTARY			
Health: Developed Countries			
Abernathy, Hershey 71	continuous space	health centres	early use of probabilistic allocation
Calvo, Marks 73	hierarchical p-median	health centres	early model of hierarchical system
Cerveny 80	warehouse formulation	bloodmobile staging area site selection	solved in continuous space, adjusted to practical location
Curtis 82	p-median	Kent, England, General Practitioners	uses weights to model differential needs
Eban-Chaime, Piskin 92	p-median with max. distance	locate system of dialysis units	small demonstration
Hardy *et al.* 73	warehouse formulation	Virginia health outreach	incorporates referral in hierarchy
Ilhan, Pierskalla 79	min transport & location costs	Chicago regional blood banks	determines number & locations of blood banks, allocation to hospitals
Malczewski, Ogryczak 90	m-o	Warsaw paediatric hospitals	analyst/decision maker interaction in m-o environment
Malczewski 91	m-o	Warsaw paediatric hospitals	m-o model trades off access costs & pollution
Mohan 83	p-median	England health services	evaluates proposed systems using LA
Morrill, Kelley 69	p-median	Chicago hospitals	uses demand threshold constraint
Shuman *et al.* 73	maximize utilization	Allegheny County Pennsylvania, ambulatory care centres	utilization is a function of travel time
Health: Developing Countries			
Bennett *et al.* 82	coverage	Columbia rural health workers	considers environmental factors
Church, Eaton 87	covering hierarchical	hierarchical health facilities	review of hierarchical structures discussion of various objectives

Name and Date	Model Structure	Real World Application	Comments
Dökmeci 77	multi-Weber	hierarchical health facilities	level-by-level heuristic
Dökmeci 79	m-o hierarchical		early use of hierarchical LA
Hodgson, Valadares 83	p-median	Goa, India PHC centres	
Hodgson 88	hierarchical max benefits based on interaction model	Goa, India PHC centres	benefit attributed to facility size & proximity
Narula, Ogbu 79	hierarchical p-median	hospitals & health centres	early use of hierarchical LA
Oppong, Hodgson 94	p-median & MCLP	hierarchical health care centres, Suhun, Ghana	p-median for primary access, MCLP for "higher up" control & assistance
Tien *et al.* 83	hierarchical		discussion of hierarchical structures
Tien, El-Tell 84	hierarchical	Jordan health care	
Willamowsky *et al.* 95	three facilities on a line	cities of refuge in biblical Israel (circa 5000 B.C.)	God commanded
Recreation, Daycare, Education			
Alonso, Devaux 81	m-o g-p	day care in unnamed 12 zone city	three objectives
Goodchild, Booth 80	probabilistic allocation	London, Ontario swimming pools	uses gravity model for probabilistic allocation
Gregg *et al.* 88	Marginal costs & distance	Queens, NYC, libraries: siting & closing	stochastic programming -- evaluates planner's suggestions
Hall 73	constrained p-median	high schools in South Chicago	constraints on racial mix & maximum distance
Holmes *et al.* 72	p-median, max distance limit	Columbus, Ohio daycare centres	introduces max distance limit to p-median approach
Hodgson, Doyle 78	p-median, max distance limit	Edmonton, Canada daycare centres	considers travel implications for 2 mobility groups
Hodgson 81b	min diversion from predetermined paths	Edmonton, Canada daycare centres	introduces notion of location relative to predetermined trip paths
Koroglu 92		Turkey, schools	
November, *et al.* 96	m-o g-p	regionalization of school districts, Connecticut, USA	selection of best from alternatively weighted scenarios
Robertson 78	p-median	Glasgow, Scotland, recreation centres	
Tewari, Jena 87	p-median	Karnataka, India high schools	LA used to assess actual decision-making

Name and Date	Model Structure	Real World Application	Comments
Transportation			
Ball *et al.* 84	warehouse structure	urban mass transit garages	examines components of fixed & operating costs
Bouliane, Laporte 92	set covering	postal relay boxes	distribution points for postman's refills
Flynn, Ratick 88	m-o, min cost, max coverage	USA essential air services	considers compulsory services with low demand
Hodgson 81a	hierarchical max consumers' welfare	Edmonton, Canada auto registration outlets	uses gravity model for probabilistic allocation
Jarvis, Unger 78	minimize deadhead time	Louisville bus routing & garage location	iterates between location & routing
Kuby, Grau 93	MIP single hub with stopovers	Federal Express package pickup in west half USA	significant improvement on pure hub and spoke
Labbé, Laporte 86	min routing & delivery costs	post box location	
List, Mirchandani 91	m-o shortest path	hazardous waste transport Albany, NY	facility siting and route/exposure minimization
List *et al.* 91	routing & facilities	hazardous rail and road	review
Maze *et al.* 83	capacitated transportation model	siting garages & buses in Detroit	first to optimally site & size garages
Mirchandani, *et al. 95*	capacitated facility location	hazardous facility inspection, flows	capacitated set covering, "refined" greedy heuristic
Ohsawa 89	linear facilities, trips exert demand	linear traffic facilities, eg: bridges	first LA work on linear facilities
Pearce 74	analytic geometry	concentric ring roads in hypothetical city	different speeds of ring travel considered
ReVelle *et al.* 91	dual objective modified p-median	nuclear waste transport, eastern half USA	siting and routing, minimizing ton-miles and tons-past-people
Rose, Bennett 92	MCLP	Victoria, Australia, road repair depots	two step: locations, sizes
Saatcioglu 82	set covering, plant location	airport location in Turkey	
Saaty 72	(multi) Weber on a line	continental USA	solved geometrically
Schneider *et al.* 76	interactive computer graphics	park and ride lots in Seattle, Washington	local full enumeration

Name and Date	Model Structure	Real World Application	Comments
Regional Development			
Al-Faraj *et al.* 93	two stage, g-p followed by *p*-median	hierarchical traffic police, Dammam, Saudi Arabia	g-p for patrol areas, MIP to group these to multiple headquarters
Banerji, Fisher 74	hierarchical set covering, p-median	hierarchical service centre locations	set covering determines facility numbers; p-median their locations
Cohon, *et al.* 80	m-o facility location	power plant location	
Current, O'Kelly 92	LSCP & MCLP	warning sirens in anonymous mid-west city	alternative cost scenarios
Hodgson 82	review article	regional development	review for developing world audience
Jasińska, Wojtych 84	two stage cap. plant location	sugar beet depots, Lower Silesia, Poland	sugar beets go direct to mill or via depot collection points
Mehretu *et al.* 83	p-median max distance limit	Upper Volta basic needs: health, schools, markets	considers mix of services
Moore, ReVelle 82	hierarchical covering	Honduras service facilities	greater covering ability for high order suppliers of low order services
Osleeb, Ratick 83a	p-median in transportation model	coal ports in New England	emphasises model used for results published in 83b
Osleeb, Ratick 83b	p-median in transportation model	coal ports in New England	emphasizes results of model published in 83a
Patel 79	min spanning tree, set covering, dynamic programming	Social service centres, Dharampur, India	locates & schedules roads and services
Psaraftis, *et al.* *86*	m-o facility location	oil spill cleanup equip. facility New England	implicit enumeration with imbedded heuristic
Ratick 83	p-median in transportation model	Northeastern USA, coal export systems	range of LA solutions analyzed by game theory
Ratick, Osleeb 83	p-median in transportation model	East coast USA, coal export systems	emphasizes fixed costs and export
Rosenfield, *et al.* 92	min distance, min facility	USA postal service	postal flows in a GIS, 3 different "large" cities
Rushton 84	review article	rural services in developing countries	excellent review
Saedt 81	heuristic LA	fodder drying, Netherlands	4 to 5 too many drier locations in use
Swersey, Thakur 95	set covering problem	exhaust inspection stations, Connecticut	improved service, decrease number of sites, $3 million saving
Thomas 84	p-median	post offices in Namur, Belgium	sensitivity of use by a multivariate logit model

Name and Date	Model Structure	Real World Application	Comments
Weston, 82	queueing theory with hierarchical 0,1	Telephone question answering USA	4 objectives
UNDESIRABLE FACILITIES			
Austin *et al.* 70	multisite	noxious facilities	early noxious facility model, uses dynamic programming
Caruso *et al.* 93	m-o heuristic LA	solid waste disposal Lambordy, Italy	
Drezner, Wesolowsky 83	max min rectilinear distance	noxious facility	demonstration of approach
Erkut, Neuman	review paper	locating undesirable facilities	concentrates on models, some applications
Fitzsimmons, Allen 83	warehouse	out-of-state tax collection offices	solution modified for political acceptability
Helms, Clark 71a	warehousing structure	solid waste disposal	
Helms, Clark 71b	warehousing structure	solid waste disposal	
Karkazis, Papadimitriou 92	min pop. weighted effect	air pollution power plant Thessalia, Greece	b&b by big square - small square
Kirca, Erkip 88	cap. warehousing structure	solid waste disposal Istanbul, Turkey	locating transfer stations
Melachrinoudis, *et al.* 95	m-o MIP	landfill location and sizing hypothetical area	
Rahman, Kuby 95	m-o and fixed cost	solid waste transshipment	six objectives including opposition, distance decay
Wirasinghe, Waters 83		solid waste disposal	incorporates nonlinear elements
Wyman, Kuby 96	m-o minimax	toxic waste treatment Phoenix, Arizona	endogenous technology choice
Zhu, ReVelle 88	fixed charge plant location	siting and pipelining sewage plants	uses gateway (chaining) constraint
Zhu *et al.* 89	fixed charge plant location	siting and pipelining sewage plants	dual analyzed for equitable cost allocation

Name and Date	Model Structure	Real World Application	Comments
PRIVATE FACILITIES			
INFRASTRUCTURE			
Aykin 95	hub locating and routing	interacting hubs located in hypothetical plane	compares heuristics
Ballou 68	dynamic warehouse location	warehouses	early use of dynamic programming
Baumol, Wolfe 58	transportation problem through potential warehouses	warehouses	no fixed costs: not a "classic" warehouse problem
Bhaskaran 92	multi-weber	collection/transshipment points	heuristic, user interactive
Bitran, Lawrence 80	m-o multi-period p-median	regional insurance offices	driven by minimum specified income per office
Bloemhof-Ruwaard *et al.* 96	plant location with waste disposal costs	hypothetical example	heuristic solutions
Brown, Gibson 72	multiplant location	manufacturing plants	condenses several location factors into a single parameter
Feldman, *et al.* 66	minimize shipping and location costs	USA cities warehouses	treats economies of scale uses add and drop heuristic
Feo, Bard 89	min cost multi-commodity set covering	American Airlines maintenance centres	solution by greedy heuristic
Klincewicz 91	*p*-hub, USA, 1970 air traffic	USA 1970 passenger air traffic	heuristics compared in 10, 12, 20, 25 USA cities
Köksalan, *et al.* 95	plant location & warehouse	new beer breweries, Turkey	one implemented, model to be reapplied for more in future
Kuehn, Hamburger 63	minimize shipping and location costs	warehouses	introduces fixed cost treatment to warehouse location
Lawrence, Pengilly 69	multiple cost minimization	locates depots to serve factories and consumers	contains barriers and forbidden sites
Love, Yerex 76	MIP with rectangular distances	relative siting concrete pole manufacturing components	siting in three dimensions
McKeown, Sutliff 77	p-median, limited potential sites	carpet factories in USA	real cost data
O'Kelly 86	min transport cost in hub system	airline hub locations	seminal presentations of hub location problem
O'Kelly 87	min transport cost in hub system	airline hub locations	seminal presentations of hub location problem
Osleeb, Cromley 78	Transportation problem	Coca-Cola distribution in Southern Ontario	production costs, demand, delivery cost each by separate models

Name and Date	Model Structure	Real World Application	Comments
Osleeb, Ratick 90	dynamic warehouse model	locates storage facilities to facilitate JiT planning	
Poulton, Kanafani 75	analytical geometry	off-airport terminals Los Angeles	also analyses London
Stollsteimer 63	transportation problem	pear processing, Northern California	feasible facility locations are road segments
Vergin, Rogers 67	plant location problem	location of economic facilities	
RESOURCE EXTRACTION			
Dykstra, Riggs 77	min distance	location of forest harvest area centroids	
Gibson, Rodenberg 75	min total shipping costs	location of transshipment points, timber harvesting	locates transshipment points on a road
Hansen, *et al.* 92	capacitated plant location	locate & size oil production platforms	optimal & TABU search
Hodgson *et al.* 87	min work	location of forest harvest area centroids	considers effects of gravity & friction on least-work sites
Nambiar *et al.* 81	cap. plant location & cap. travelling salesman	rubber smallholders in Malaysia	heuristic solution, iterative
Nambiar *et al.* 89	uncap. plant location	rubber collection & processing, Malaysia	DUALOC
Odell, Rosing 76	MCLP with capacity constraints	locate oil wells & platforms in No. Sea	maximize oil recovered for various investment strategies
Odell *et al.* 76	p-median, fixed costs	"common carrier" oil pipelines in UK No. Sea	p collector platforms & fixed cost lines to shore
Odell, Rosing 77a	MCLP with capacity constraints	locate oil wells & platforms in No. Sea	general response to criticism (Odell, Rosing 76)
Odell, Rosing 77b	MCLP with capacity constraints	maximize oil recovery in No. Sea	maximum wells per platform, various numbers of platforms
Rosing 92	full flow clustering	wells & steam generators East Netherlands	single Weber applied to each well cluster, micro-economic scenarios
Rosing, Odell 78a	MCLP with capacity constraints	locate oil wells & platforms in No. Sea	capacity on wells per platform, maximize total oil per field
Rosing Odell 78b	MCLP with capacity constraints	locate oil wells & platforms in No. Sea	specific response to criticism of model (Odell, Rosing 76)
RETAIL LOCATION			
Point Demands			
Achabal *et al.* 82	multisite use of Huff model	retail store location	first multiple store retail location model

Name and Date	Model Structure	Real World Application	Comments
Craig *et al.* 84	review article	review of retail location literature	
Fleischmann, Paraschis 88	multi-Weber	districting retail outlets for manufacturer's reps. W. Germany	uses pseudo-centres
Eiselt, *et al.* 93	special form of quadratic assignment	mall design to max pedestrian exposure	dynamic programming and greedy heuristic
Ghosh 79	p-median	India markets	evaluates against random locations
Ghosh, Craig 83	spatial interaction based	store locations	incorporates interaction model considers uncertainty & competition
Ghosh, Craig 84	max. revenue	store locations	considers competition
Ghosh, Craig, 86	modified MCLP	services, no competition	uses variant of Tietz and Bart
Ghosh, Craig 91	spatial interaction based	location of franchises	considers market cannibalization by new franchisee
Ghosh, McLafferty 82	m-o (several scenarios)	store locations	uses Huff model for allocations selects most robust m-o solution
Ghosh, Tibrewala 92	p-median in space/time	locations & timing store opening, hypothetical city	2 competing chains
Goodchild 84	probabilistic allocation	restaurant location	model incorporated into interactive graphics package
Leivo 65	diverse continuous	auto-dealerships, Finland	early attempt at retail model
Lentnek, *et al.* 92	Weber problem	producer services in a hypothetical city	considers micro-economic aspects
Rosing, Van Dijk 93	comments on Lentnek, *et al.* 92	producer services in a hypothetical city	considers micro-economic aspects
Trip-based Demands			
Berman *et al.* 92	intercept max flows in network	discretionary service facilities	relates to trip-based demand
Goodchild, Norhona 87		impulse shopping (gas stations)	suggests tradeoff between home-based & trip-based demands
Hodgson 90	capture max flows in network	impulse shopping	relates to trip-based demand
Hodgson, Rosing 92	dual objective model	impulse shopping	trades off home-based & trip-based demands
Hodgson, *et al.* 96	capture max flows in network	impulse shopping	tests Hodgson 90 on a authentic network

Name and Date	Model Structure	Real World Application	Comments
		OTHER	
Boffey, Karkasis 89	segmentation of linear network	location of transfer bridges in a LAN	relates to path-generated flows
Cornuejols *et al.* 77	min distance	location of bank accounts	excellent analysis of heuristic bound-generating algorithms
Davis *et al.* 89	2 level p-median	location of check processing in Ohio	solved with primal network algorithm
Hakimi 64	p-median	switching centres in communication networks	seminal discrete location paper
Hakimi 65	p-median	switching centres in communication networks	seminal discrete location paper
Min 89	p-median	branch banks in Columbus	p-median in multivariate fuzzy system

Name and Date	Model Structure	Real World Applications	Comments
		ACADEMIC	
Bell, Church 85	hierarchical p-median	deducing Maya lowland settlement patterns	interesting application
Bell, Church 87	hierarchical dual coverage objective	deducing Nile settlement patterns	
Eiselt 92	review paper	location modelling applications	good review
Fotheringham, *et.al* 1995	p-median Buffalo, NY	aggregation error	concludes nearly anywhere equally good depending on aggregation
Hanjoul *et al.* 90	facility location	plants in USA	three different spatial pricing policies compared
Harvey *et al.* 74	hierarchical p-median	investigating historical city system	considers altering colonial city structure
Hodgson *et al.* 93	review paper	location modelling applications	excellent compilation
Hogan 90	MCLP, p-median and three multi-criteria cluster	experimental watersheds, Arizona	compares effectiveness of coverage by five different designed nets
Horn 95	regionalization	build constituencies, Australia	interchange heuristic with side constraints
Kohsaka 83	hierarchical warehouse	LA problem models central place system	early attempt to model central place theory

Name and Date	Model Structure	Real World Applications	Comments
Kuby 89	hierarchical	models Lösch central place system	attempts to operationalize central place theory laws
Meyer, Brill 88	MCLP	siting wells for monitor-ing ground water	monte carlo simulation of contami-nation, maximising plume coverage
Monmonier 71	min distance	class interval selection in cartography	experiments with LA approaches to classification
Rosing, ReVelle 1986	full flow clustering	defining labour market regions W. Netherlands	defining regions later used in a spatial econometric study

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