The Tree of Hub Location Problem with Inter-hub stopovers.

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modelis Modélisation Optimisation Décision

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Abstract

This research focuses on the strategic design of networks, in particular for waterborne transportation withing a context of physical internet. In the special case of river transport, the underlying topology corresponds to a tree. We relaxed some assumptions for classic Hub Location Problems. 1st we can have elements located between inter-hub arcs, thanks to this relaxation we introduced a new element for the network, it is called stopovers. And 2nd, we can have direct shipments of demanded commodities between origin i and destination j. Two Strategic decisions are taken: 1) location of hubs and stopovers and 2) allocation of spokes to hubs. A MILP formulation was proposed. The objective function is formulated to minimize the overall transportation costs for demanded. A set of valid inequalities was also proposed to improve the LP bound. Computational experiments were performed using actual data from the Illinois waterway.

Our starting point is the hub location problem (HLP)

The HLPs are classic optimization problems in which one must establish the best possible location for hubs and allocate the spokes to them. The network stakeholders can achieve economies of scale if they use the hubs to consolidate, sort and distribute the commodities between nodes.

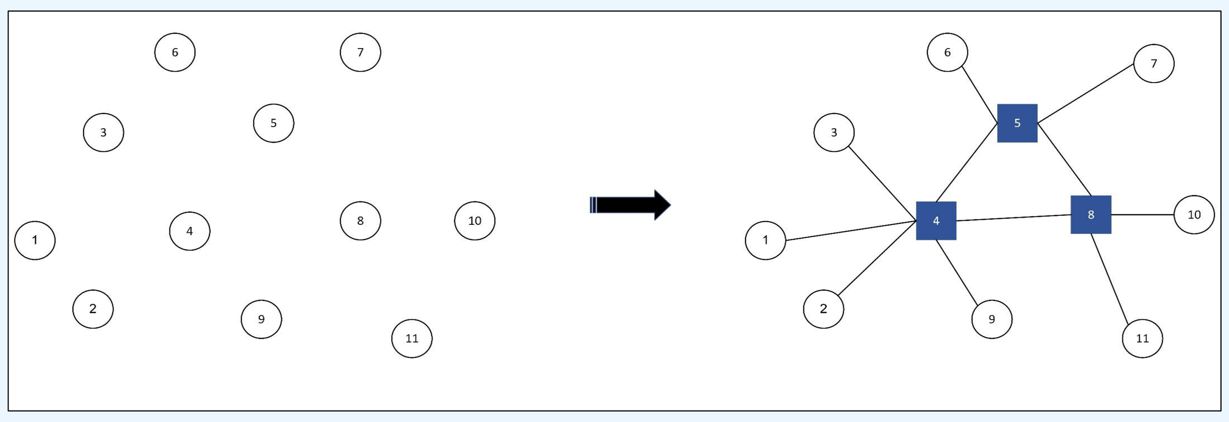


Figure 1: the Hub Location problem

Introducing a new type of nodes : stopovers

- Stopovers are located on inter-hub links, not between hubs and spokes
- The proposed topology with stopovers can reduce the number of transshipments.
- It can also reduce the operational costs.

- Stopovers are particularly suitable on tree-type networks.
- This leads to **the tree-of-hubs location problem with stopovers.**
- Possible fields of applications: maritime, waterborne or rail transportation, full truckload transportation, energy networks…

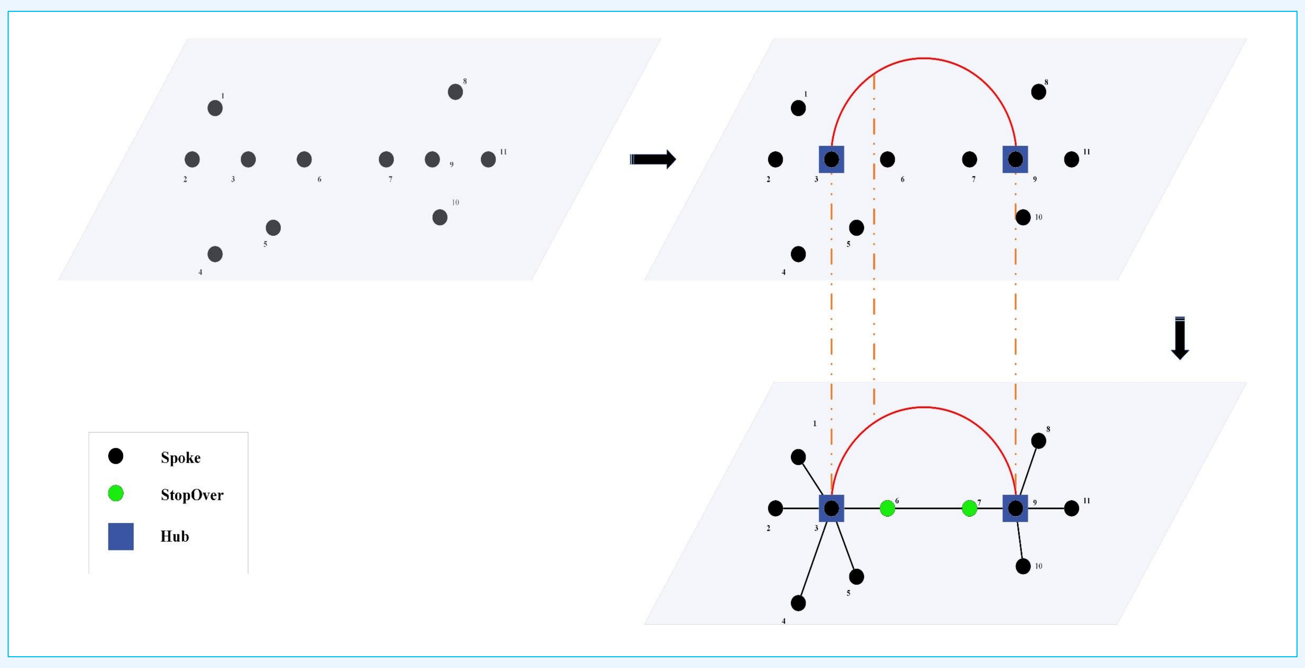


Figure 2: Graphical representation of the Tree of Hub Location with stopovers

MILP formulation of the problem

Problem decisions	Mathematical model assumptions
Hub and stopover location Spokes allocation	Classical assumptions for hubs and spokes are still valid The network restricted to hubs and stopovers is a tree Direct deliveries from an origin i to a destination j are possible. Split of demand is allowed

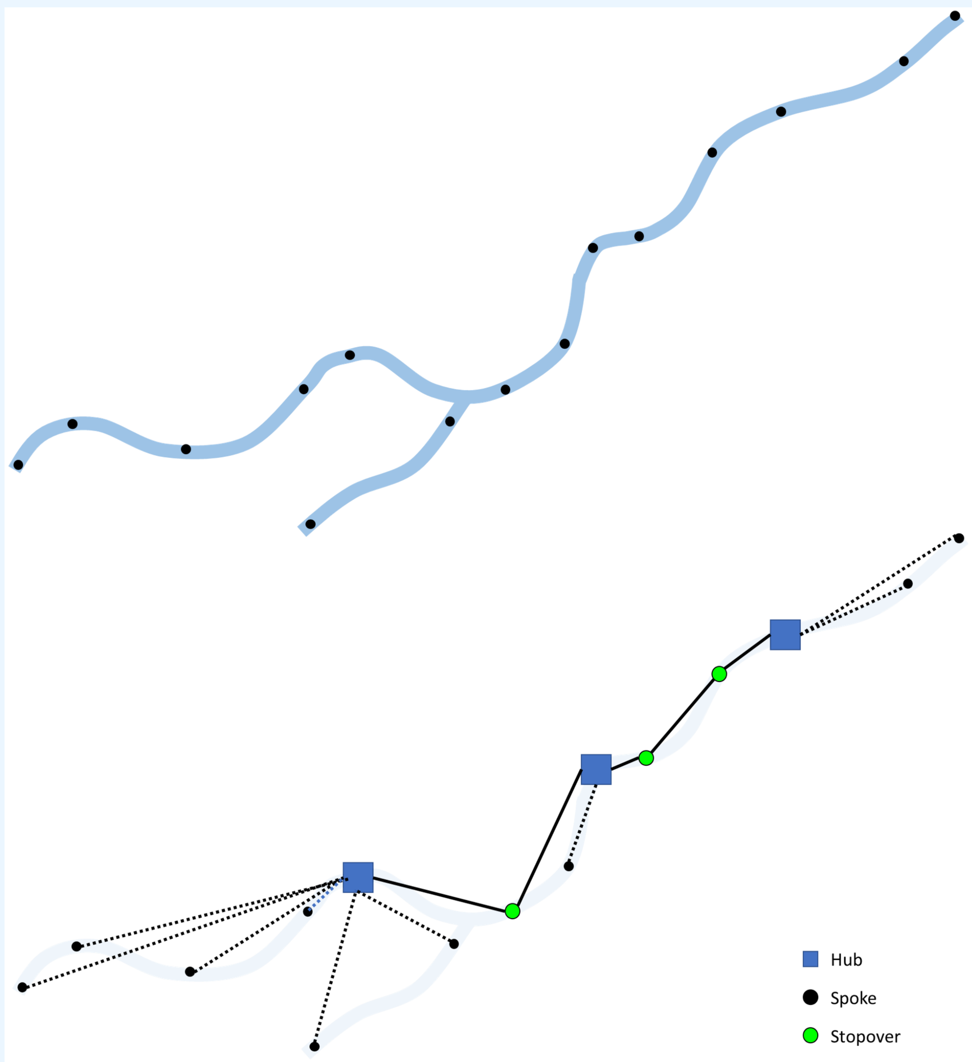
Results of numerical experiments on a case study (data generated from Illinois waterways, USA)

Problem			thlp-so + NC	
n	α	β	%gap	CPU(s)
	0,2	0,36	0	15
	0,2	0,6	0	14
	0,2	0,84	0	19
	0,5	0,6	0	1
10	0,5	0,75	0	7
	0,5	0,9	0	14
	0,8	0,84	0	6
	0,8	0,9	0	10
	0,8	0,96	0	17
	0,2	0,36	0	2789
	0,2	0,6	9%	7200
	0,2	0,84	0	1052
	0,5	0,6	0	155
15	0,5	0,75	0	925
	0,5	0,9	0	5715
	0,8	0,84	0	81
	0,8	0,9	0	110
	0,8	0,96	0	279
	0,2	0,36	11%	7200
	0,2	0,6	23%	7200
	0,2	0,84	10%	7200
	0,5	0,6	0	6894
20	0,5	0,75	11%	7200
	0,5	0,9	18%	7200
	0,8	0,84	0	496
	0,8	0,9	0	3478
	0,8	0,96	0	6866

Problems with 3 hubs

Problem			thlp-so + NC	
n	α	β	%gap	CPU(s)
	0,2	0,36	0	37
	0,2	0,6	0	38
	0,2	0,84	0	9
	0,5	0,6	0	25
10	0,5	0,75	0	14
	0,5	0,9	0	9
	0,8	0,84	0	7
	0,8	0,9	0	7
	0,8	0,96	0	12
	0,2	0,36	4%	7200
	0,2	0,6	5%	7200
	0,2	0,84	0	573
	0,5	0,6	0	340
15	0,5	0,75	0	532
	0,5	0,9	8%	7200
	0,8	0,84	0	322
	0,8	0,9	0	308
	0,8	0,96	0	1016
	0,2	0,36	19%	7200
	0,2	0,6	28%	7200
	0,2	0,84	5%	7200
	0,5	0,6	7%	7200
20	0,5	0,75	16%	7200
	0,5	0,9	0	4047
	0,8	0,84	0	2983
	0,8	0,9	3%	7200
	0,8	0,96	5%	7200

Problems with 5 hubs



Graphic representation for the solution of an instance.
Source : Oscar A.

Conclusions

- The use of stopovers contributes to significantly reduce the traveled distance
- The stopovers slightly increase the traveling time of some commodities, and significantly decreases the traveling time of all commodities that use the stopovers.
- The use of stopovers avoids costly backward trip and transshipment : this educes operational costs.
- The process to define the network is complex despite the fact the tree is already established in a river.

Future work

- Develop a heuristic or exact solution method to tackle medium and large scale problems.
- Extend the model by considering the distances and demands from ad-hoc cities that are not located on the river (but not too far).
- Enrich the model by considering the interconnections with other types of networks, e.g., maritime, rail, roads...
- Consider constraints on capacity, frequency and transportation modes, so the environment modeled will be closer to an actual one.

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