# Open-source geospatial software for location cover models

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**Summary**

Location cover models are aimed at siting facilities in order to provide efficient service to demand. These models play a crucial role in the strategic planning and management of service systems. For this reason, they have been incorporated in various geographical information systems software packages. Although open-source tools are promising for location cover modelling, there is a lack of comprehensive review of these tools. This paper presents a critical review of the open-source tools that support location cover models in terms of assumptions, solution approach, and computing performance. A case study of store location planning in San Francisco is used to highlight comparative aspects of performance.

**KEYWORDS:** open source; location cover models; spatial optimisation; GIS

## 1. Introduction

Location modelling is central to the strategic planning of service systems in both public and private sectors. In the public sector, the location choices of service facilities involve not only fiscal responsibility but also social benefits and accessibility (White 1979). For instance, local governments provide a range of public services, such as libraries and schools, in order to maximise accessibility to people in the community. In the private sector, stores and distribution centres are located in order to best serve customers and optimise revenue.

Location modelling has long been supported in geographic information systems (GIS). In particular, commercial GIS packages such as ArcGIS and TransCAD formulate and solve location models using heuristic methods (Murray *et al.* 2019). Heuristic methods often identify solutions efficiently, requiring less computational resources, but they are likely to produce sub-optimal solutions. Moreover, results obtained for location models in ArcGIS or TransCAD based on heuristic methods may not be reproducible. The heuristics within these packages involve many parameters that affect speed and solution quality, but the technical details of the heuristics are hidden from users. The code is not open to the user. There are no mechanisms for users to know or interact with the parameters of the heuristics.

In contrast to commercial packages, open-source software is a promising option for applying location models because of many advantages. First, under open source, the transparency and reproducibility of a method are guaranteed, which eliminates the “black box” that hides implementation details (Rey 2009, 2018, Singleton *et al.* 2016). Second, open-source software facilitate access to the source code for use, audit, and modification. Third, users are allowed to extend open-source software to fit their requirements. Although open source does not imply free of charge, most open source software is accessible at no or little cost.

While development and application of location cover models has been increasing, there is a lack of critical review of the capabilities of open source tools to support such analysis. This paper provides a review and comparison of open-source approaches for location cover models in terms of their assumptions, capabilities, and computational efficiency. We focus on three open source packages for location cover models, namely PySpatialOpt (Pulver 2019), Maxcovr (Tierney 2019), and FPL Spreadsheet Solver (FPL_Solver for short) (Erdoğan 2019, Erdoğan *et al.* 2019). ArcGIS is used as a

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benchmark for comparison. Regarding location cover models, we focus on two representative and widely used modeling approaches, namely the Location Set Cover Problem (LSCP) and Maximal Cover Location Problem (MCLP).

## 2. Methods

This section describes the two representative location cover models. The LSCP (Toregas *et al.* 1971) represents planning scenarios where the fewest facilities are to be sited in order to serve all demand within the designated service standard. The MCLP (Church and ReVelle 1974) was introduced to select the locations of facilities of a fixed number that serve the most potential demand within the designated service standard, representing a generalization of the LSCP.

## 3. A comparison of open-source location cover software

An analysis that uses a location cover model follows a basic workflow similar to that shown in Figure 1. Using this workflow, we provide a multifaceted comparison of the tools that support location cover modeling, which is summarised in Table 1.

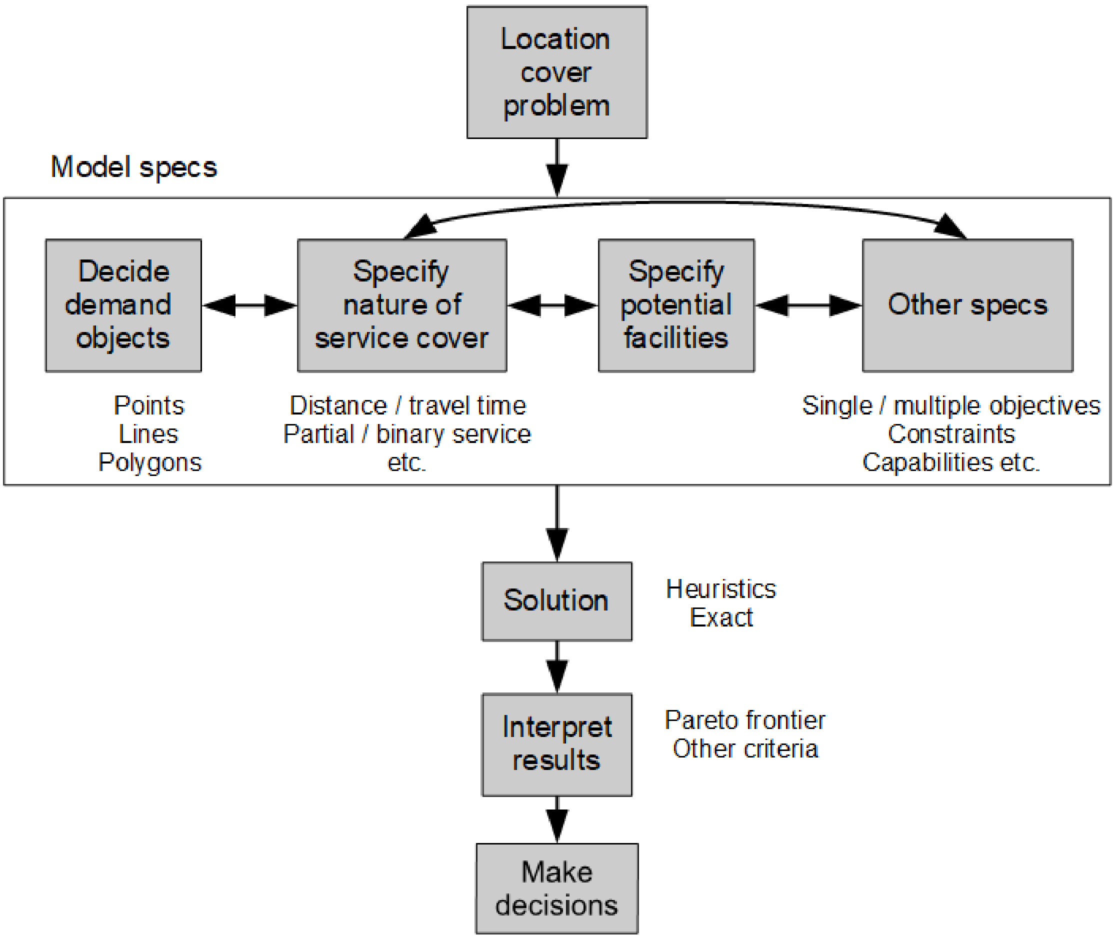


Figure 1. The workflow of using a location cover model (adapted from Chen *et al.* 2021)

Table 1. A comparison of tools that support location cover modelling

| | ArcGIS | PySpatialOpt | Maxcovr | FLP_Solver |
|---|---|---|---|---|
| Model type | MCLP, LSCP | MCLP, LSCP, others | MCLP, LSCP | MCLP, LSCP, others |
| Allowing for facility capacity | Yes | No | No | Yes |

| | | | | |
|---|---|---|---|---|
| Shape of demand object | Point | Point, polygon | Point | Point |
| Demand weight | Variable | Variable | Variable | Variable |
| Space | Road network space | Unrestricted | Unrestricted | Unrestricted |
| Distance metric | Network distance | Unrestricted | Unrestricted | Unrestricted |
| Solution approach | Heuristic | Exact | Exact | Heuristic |

All four tools provide access to MCLP and LSCP, and PySpatialOpt and FLP_Solver also support other location models. On the other hand, no all of these tools allow for specifying a capacity for each facility. While ArcgIS and FLP_Solver allow for differing capacities of facilities, PySpatialOpt and ArcGIS require that each facility has an unlimited capacity. In terms of spatial representation of demands, these tools require demands as points except for PySpatialOpt which can represent demand as points or polygons.
The distance metric or travel time between demand and facilities is important for location cover models. In particular, ArcGIS requires a transport network in order to formulate and solve location models, and all the other tools are flexible with distance metrics.
One primary difference between these tools is the solution approaches for solving location cover models. PySpatialOpt and Maxcovr provide optimal solutions using exact algorithms, which are supported by optimisation solvers (e.g. lp_solve, Gurobi, CPLEX, GLPK). On the other hand, both FLP_Solver and ArcGIS produce solutions to location cover models using heuristic methods, meaning that there is no guarantee that the generated solutions are optimal.

## 4. Case Study

We present a case study to compare the function and performance of the four tools discussed in this study. All processing and computation were conducted on a remote desktop computer (Intel Xeon E5 CPU, 2.7 GHz with 256 GBytes memory).
The case is about store location planning in San Francisco that would maximise business. The objective is to locate stores in 16 potential sites that are close to population centres, which are represented by the centroids of the 205 census tracts in the city. The maximum service distance to access a store is assumed to be 5 kilometres on the road network.
The LSCP was applied to this case to determine the minimal number of stores needed to cover all population centres. As demonstrated in Table 2, all four tools obtained the optimal solution regarding the number of facilities needed. However, the computational efficiency varied, with PySpatialOpt and Maxcovr being the most efficient and FLP_Solver being the least efficient.

Moreover, the MCLP was applied to assess the coverage of fewer facilities. We consider siting between one and twelve stores and summarise the findings in Table 2. all four tools provided solutions of the same and optimal coverage, but differed significantly in the solution time. While ArcGIS required 12.66 seconds on average, PySpatialOpt and Maxcovr took only 0.24 and 0.01 seconds. In addition, the solution time of FLP_Solver was close to 60 seconds.

Table 2. LSCP and MCLP results for the San Francisco case

| | ArcGIS | PySpatialOpt | Maxcovr | FLP_Solver |
|---|---|---|---|---|
| Number of facilites needed in LSCP | 8 | 8 | 8 | 8 |
| Computing time of LSCP (s) | 12.8 | 1.3 | 0.01 | 60 |
| Number of optimal solutions out of 12 MCLP | 12 | 12 | 12 | 12 |
| Average computing time for 12 MCLP (s) | 12.6 | 0.2 | 0.01 | 65 |

## 5. Conclusions

This paper has investigated location cover models available in open-source tools, and the results are compared with those using ArcGIS, a proprietary software package. Overall, PySpatialOpt and Maxcovr outperform FLP_Solver in terms of computing performance as demonstrated in a case study. While open-source software is promising for location cover models, further work is needed regarding the quality control and maintainability, as suggested in Steiniger and Hunter (2013).

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