

# Integration Strategies for GIS and Optimization Tools



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## INTRODUCTION

GIS is a powerful tool for addressing decision making situations mainly when spatial data are involved in the decision process. It offers the opportunity of managing voluminous spatial data in the sense that numerous functionalities are available for the decision maker (DM) in order to take a rational decision in terms of the displayed data either in a cartographical or in a numerical format. Although GIS disposes of numerous advantages, some limitations arise when trying to look for more complex problems. In order to improve the quality of the generated solutions, we propose to integrate in the GIS framework some optimization routines. In fact, optimization disposes of a panoply of solution approaches that generate, depending on the problem complexity, the suitable technique as reported in Li et al. (2011) as well as in the multicriteria decision making (Malczewski 2006). This article deals with the integration of the two systems in the hope of improving the efficiency of the resulting framework that we call “GIS-O.”

The survey of GIS-O can be classified into three main categories namely the full, the loose and the tight integration strategies. We expose the main advantages and drawbacks of each strategy and illustrate them by some potential applications (Faiz and Krichen 2013). This survey makes easy to see that the more appropriate GIS-O integration strategy is application dependant. A special attention dedicated to the class of transportation problems that will be the main potential application for which we propose a specific integration approach that manages the data from the geographical database (GDB) and solves the obtained problem to be later

plotted on the map. More specifically, we address the capacitated vehicle routing problem (CVRP) characterized by the minimization of the travel cost under structural constraints. We propose a loose-based SDSS for the CVRP that handles QGIS as a geographical information system and the CPLEX optimizer followed by a tabu search metaheuristic as exact and approximate approaches, respectively.

## BACKGROUND

A close analysis of the literature reveals that GIS is able to solve a wide range of spatial decision problems from numerous fields of study as environment and ecology (Rossi and Villa 2009), waste management (Alvarez et al. 2007), urban planning (Li 2011) and transportation (Perpina et al. 2009). Meanwhile, some inefficiency arises when using solely the GIS since it does not contain advanced functionalities that yield to the finding of optimal solutions or interactive decision support systems. The GIS-O literature can be resumed in three main classes of integration strategies.

### The Full Integration

Optimization routines are entirely embedded in the GIS or conversely. A first attempt of a GIS-O integration consists in fully hosting one system’s operations into the other. The resulting system corresponds to one of the master-slave scheme, as evoked in Brandmeyer and Karimi (2000). As in most cases, we speak about a complete integration of optimization routines into GIS. Huang and Jiang (2002) encouraged the use of

the GIS macro language as it ensures the stability and durability of the full integrated system, once optimization routines are to be integrated.

## The Loose Integration

An alternative strategy for integration GIS and optimization, called the loose integration, consists in keeping each system apart and allowing the information exchange in the sense that the output of one system serves as input for the other.

Technically, the link between the GIS and the optimization component is managed via a common graphical user interface (GUI) that simulated the obtained framework as a single system that interacts easily with the DM.

## The Tight Integration

The tight coupling strategy that embeds some functionalities within the GIS and lets less utilized ones apart. Hence, the tight integration can be seen as a hybridization of the two previous approaches. In fact, it allows the sharing of communication protocols and a common user interface that avoids the problems of incompatibility.

Such architecture is adopted in the literature as it is the less requiring in terms of resources and the most portable environment.

It was shown in Faiz and Krichen (2013) that the use of each strategy is problem-dependant as the functionalities required in each context can be evaluated by frequency of use and complexity. The compatibility

of the framework is indeed as a determinant factor in selecting either integration strategy since it permits substituting one subsystem by another without any additional cost. All such features detailed in the next section.

## Comparative Study

Based on the three main designs of integration strategies, we dress in what follows the most relevant evaluation criteria for integrating GIS and optimization in Table 1.

In terms of these features, mainly the required time for the integration and the integration cost, the loose coupling seems to be promising once adopted. Based on these arguments, we propose to develop in the remaining of this article a loose integration that resorts to GIS and optimization tools specifically designed for solving the CVRP.

## DESCRIPTION OF THE CAPACITATED VEHICLE ROUTING PROBLEM

The CVRP is a spatial optimization problem that involves a set of customers to be supplied by vehicles already loaded by their respective orders. This problem requires a design of the vehicles loads and a pathway for each vehicle that starts and ends at the depot, while fulfilling structural constraints. The CVRP is a vehicle routing problem (VRP) with capacity constraints. The VRP in its basic version (Laporte 1992) tries to

*Table 1. Relevant evaluation criteria for integrating GIS and optimization*

	Full	Loose	Tight
Data transfer	Fast	Moderate	Low
File conversion	Internal GIS format	import/export formats	Both
Programming language	Advanced languages and GIS macro languages	Advanced languages	Advanced languages and GIS macro languages
GUI	The existing GUI is enriched by further functionalities that allow the management of the whole system	The existing GUIs lying to the GIS and the optimization techniques or a new GUI specifically designed to be friendly for the DM	The existing GUI is enriched by further functionalities that allow the management of the whole system
Required time	Long	Short	Moderate
Integration cost	High	Moderate	High

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