**A Survey of GIS applications in Operations Research**

*Avijit Sarkar, School of Business, University of Redlands, 1200 E. Colton Avenue, Redlands, CA 92373, 909-748-8783, avijit\_sarkar@redlands.edu*

**ABSTRACT**

The last decade has witnessed a reasonable growth in the use of Geographic Information Systems (GIS) towards the efficient solution of complex operations research (OR) problems. This research surveys instances of GIS infusion in OR during the period 1990 – 2008 and finds evidence of such infusion in problems that can be classified as vehicle routing, logistics and supply chain management (SCM), and site location. Each article is analyzed in terms of specific application, the role of GIS, the role of OR, and benefits derived. Trends are identified from the surveyed applications and scope of GIS infusion in unexplored areas is also outlined.

**Introduction**

Fierce competition in today’s global markets, the introduction of products with shorter and shorter design and life cycles, and heightened expectation of customers have forced business enterprises to invest in and focus much attention on their supply chains. This, coupled with advances and evolution in the fields of information systems, communication and transportation technologies has motivated the continuous improvement of management of supply chains and logistics networks. According to the Council of Supply Chain Management Professionals (CSCMP), logistics management is that “part of SCM that plans, implements, and controls the efficient, effective forward and reverse flow and storage of goods, services and related information between the point of origin and the point of consumption in order to meet customers’ requirements”. In summary, companies depend on their logistics systems to move materials, goods, equipment and people among supply chain partners.

**The logistics network and GIS**

The logistics network consists of suppliers, warehouses, distribution centers, retail outlets, as well as raw materials, work-in-process inventory, and finished goods that flow between the different facilities which are part of the network. Key strategic decisions pertaining to any logistics network configuration include determining the optimal number, location, and size of warehouses, allocating space for products in each warehouse, determining which products need to be transported, and in what quantities, and determining the best routes for vehicles in a transportation network. Clearly the role of geographical information in logistics network management is all too evident. An often-cited statistic in scientific literature is that 80% of business data has a geographical element, and hence geographical information systems (GIS) are playing an increasingly important role in any area of business. A GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analyzing, and displaying all forms of geographically referenced information. GIS applications cut across industry domains. GIS is used by businesses to provide solutions for customer and market analysis, site selection, risk analysis, territory and asset management, SCM, and logistics. The use of GIS towards superior management of business logistics is a relatively new phenomenon. More specifically, GIS has been employed to answer several logistics-related business questions such as: (a) what is the best route for delivery trucks? (b) How should deliveries be scheduled? (c) What mobile resources are available? (d) What is the best policy to optimize territory? (e) Where is the best site for delivery hubs?

**Literature Review**

Since instances of GIS infusion in OR are published primarily in two broad domains – OR and Geography, the search for research articles encompassed these two disciplines starting from 1990 when GIS technology started gaining popularity. Several databases such as ABI/INFORM were searched thoroughly over a 3-4 month period using a combination of phrases such as “geographic information system”, “site location”, “vehicle routing”, etc. The search yielded approximately 90 articles in mainstream OR journals (such as Interfaces, Journal of the Operational Research Society, European Journal of Operational Research, Computers and Operations Research, etc), and geography journals. It is clearly evident that since 1990, the use of GIS to facilitate the solution of complex problems in logistics and SCM (9 articles), vehicle routing (33 articles), and site location (32 articles) has steadily increased.

**GIS in logistics**

Weigel and Cao [6] applied GIS in conjunction with OR techniques to solve technician dispatching and home delivery problems at Sears. Sears used a vehicle routing and scheduling system based on a GIS to run its delivery and home service fleets more efficiently. Although the problems to be solved can be modeled as vehicle routing problems (VRP) with time windows, the size of the problem and thus practical complexity make these problems of both theoretical and practical interest. The authors constructed a series of algorithms, including an algorithm to build the origin and destination matrix, an algorithm to assign resources, and finally algorithms to perform sequencing and route improvement. The combination of GIS and OR techniques reduced driving times by 6%, increased number of service orders a technician completed per day by 3%, reduced overtime by 15%, consolidated routing offices from 46 to 22, and achieved annual savings of $9 million.

Camm et al. [1] analyzed the North American (NA) operations supply chain of Proctor and Gamble, more specifically its product sourcing and distribution system. The authors disaggregated the problem into a warehouse location component and a product sourcing and distribution component and proposed a methodology which merged integer programming and network optimization within a GIS framework. By dividing the problem into two major components, simpler models could be applied. As a result, P&G was able to consolidate its NA facilities by 20% which saved $200 million in pretax costs every year.

**GIS for vehicle routing**

Erkut, Myroon, and Strangway [3] optimized locations of service facilities as well as specialty service vehicles of an electric company thereby maximizing service coverage. The facility location problem was formulated as a *p*-median problem and solved using a greedy heuristic approach; the specialty vehicle location problem was formulated as maximal covering problem. GIS assisted in digitizing locations of demand points, facilitated aggregation of demand points via visual approximation. GIS enabled spatial analysis pruned several potential locations based on poor highway access and facilitated drive-time analysis of service facilities. Due to a very tight project deadline, all customer locations (demand points) could not be digitized, hence GIS was used for approximate aggregation of demand points. GIS allowed the authors to dissect each solution in real-time, rationalize the results, explain the strength and weaknesses of the methods used, and demonstrate the output results of the location and routing algorithms such that decision makers could build confidence in the proposed solution procedures. The marriage of GIS and OR reduced annual operating cost by $4 million.

Tarantilis and Kiranoudis [5] present a spatial decision support system (SDSS) which uses heuristics to solve the VRP. The architecture of the SDSS integrates a relational database management system within a GIS framework. The authors report that the GIS framework allows efficient representation of the transportation network of Greater Athens, Greece, and allows for the fast implementation of routing routines which solve real-life computationally intensive VRPs quickly.

**GIS in site location**

Miliotis, Dimopoulou, and Giannikos [4] have developed a hierarchical location model for locating bank branches in a competitive environment. The authors have combined demand-covering models with a GIS to capture various geographical, social and economic criteria as well as local competition concerning the demand for banking services. The hierarchical location model involves first solving a location set covering model to determine the minimum number of bank branches followed by solving a maximal covering location problem to maximize demand coverage for individual branches. GIS organized large volumes of data and also transformed all useful information to input files for the demand covering models very efficiently. The GIS framework allowed for the simulation of alternative scenarios in Macedonia, Greece, and produced useful displays for the efficient planning of financial networks.

Church [2] contains a review of existing work that forms the interface between GIS and location science and discusses future research directions involving both GIS and site location. The author concludes that demand for better location model functionality in GIS software will grow and the success of many site location applications in the future will be intimately linked to GIS.

**Conclusions and Directions for Future Research**

This abbreviated review clearly reveals that research into GIS applications in logistics is still at a nascent stage. Numerous opportunities to exploit geographical relationships and constraints within activities in the supply chain and to support different levels of logistics decision-making still exist. While some applied research exists in the domains of site location and vehicle routing, the development of GIS-aided theoretical models related to territory optimization and asset management is largely unexplored and serves as a future research direction.

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