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Enhancing market service and enterprise operations through a large-scale GIS-based distribution system

Wei Gu[a], Krista Foster[b], Jennifer Shang[b,*]

[a] Donlinks School of Economics and Management, University of Science and Technology Beijing, Beijing 100083, China
[b] Joseph M. Katz Graduate School of Business, University of Pittsburgh, Pittsburgh, PA 15260, United States

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ABSTRACT

We develop a large-scale service information system integrating market analysis, customer relationship management (CRM), and distribution service optimization. The system is based on geographical information systems (GIS), and the goals include reducing the distribution cost, increasing the efficiency, satisfying customer demand, and improving service quality. We discuss in detail the design of the model and the implementation of the system. The main contributions of this work are: (1) proposing a new workload evaluation method based on statistical analysis of the large data set. The workload measure is based on GIS and enterprise databases, which address the workload imbalance issue in distribution; (2) implementing an optimal distribution model to serve nearly a hundred thousand retailers. The model contains two stages and uses a Cluster-First-Route-Second approach. In the clustering stage, we improve the K-means method; while at the routing stage, we design a hybrid heuristic algorithm for GIS data by employing the genetic algorithm and simulated annealing techniques; and (3) integrating market analysis, CRM, and distribution service optimization to improve market service and enterprise operations.

1. Introduction

The rapid development of informatics and the continued popularity of the Internet have driven the growth of e-commerce. As e-commerce develops, the number of customers or clients increases. High-frequency distribution and quick-response logistics are necessary for effective product delivery and customer service. Timely and accurate order fulfillment is thus vital for e-commerce success, but it poses a significant challenge to businesses. In developing countries, especially in China, the most populated country on earth, the customer base is huge but its logistics performance is less than perfect. To improve logistics efficiency and effectiveness, we develop a large-scale decision support system to optimize marketing service and enterprise operations. The information system integrates market analysis, customer relationship management (CRM), and distribution resource planning using data from geographical information systems (GIS). We strive to reduce costs, meet customer expectations of quality, excel in responsiveness, and improve operations efficiency and flexibility.

This research was motivated by the needs of a fast-moving-consumer-goods (FMCG) supply chain (SC) that ships its products to more than 90,000 retailers, which serve 24 million consumers dispersed throughout Innner Mongolia in Northwestern China. Annually, more than 1,150,000 customer orders and 13 million cases of products are shipped with $2.82 billion revenue. FMCG are characterized by short shelf life (sold quickly) and low cost, e.g. soft drinks and over-the-counter (OTC) non-prescription drugs. The distribution center faces many challenges. Currently, the company uses human judgment based on experience and instinct for distribution management and work allocation. Due to the complexity, the resources and distribution schedules remain nearly fixed once the company decides on them. However, customers' demands and locations change from time to time, the types of delivery vehicles and goods may be mismatched, and deliverymen's and drivers' experiences vary. All these lead to waste, workload imbalance, and high distribution costs. The company is in need of a more sophisticated and practicable information system to optimize the logistics distribution process.

Fig. 1 shows the distribution of customers in Inner Mongolia and Baotou City. The retailers (the green diamonds) are dispersed in 14 cities in Inner Mongolia. Our study focuses on Baotou City. It is located in the east of Inner Mongolia. The city spans 28,000 km^2, and there are nine districts. The resident population in Baotou is 2.55 million, including 1.8 million urban residents. There is one regional distribution center in the downtown area with five customer transfer stations (the red circles). In total, 9494 retailers

* Corresponding author. Tel.: +1 412 648 1681.
E-mail addresses: guwei@ustb.edu.cn (W. Gu), kmf88@pitt.edu (K. Foster), shang@katz.pitt.edu (J. Shang).

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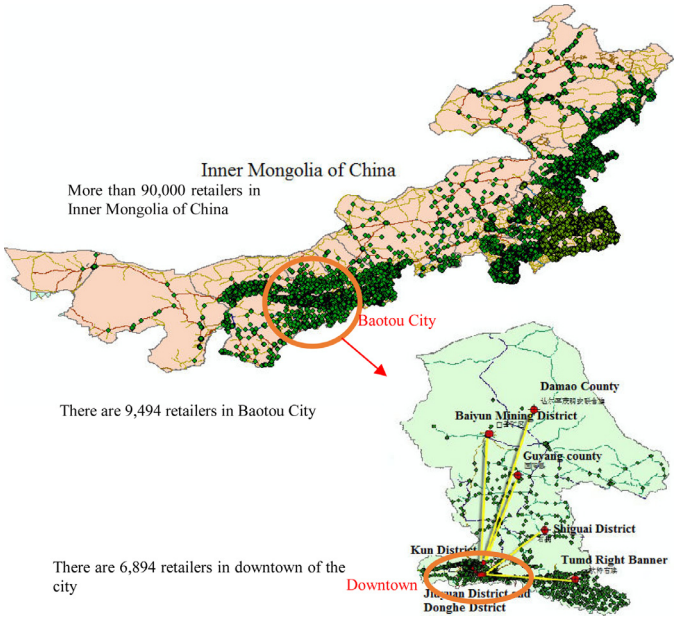

Fig. 1. Distribution of customers in Inner Mongolia and Baotou City.

demand 14,000 cases of products annually. The methods developed for Baotou City in this research are generalizable and are used for other cities as well.

We develop the large-scale distribution support system in order to: (1) reduce distribution costs; (2) resolve the workload imbalance problem among different clusters; (3) improve customer service through marketing, delivery, and quick-response; and (4) build a GIS-based large-scale logistics distribution system, which integrates market analysis, CRM, and distribution requirement planning.

We make use of the powerful geospatial data analysis capabilities of GIS for logistics planning. It mainly processes and analyzes space. Our model applies dynamic and real-time GIS data to optimize distribution system. The solution is practical and can be viewed on the electronic map. However, there are some issues which must be addressed in the application of the GIS technology. First, collecting and updating all geographical data attributes for all customers is complicated. Second, decisions regarding how to integrate the GIS spatial analysis with the distribution model must be made. Third, the solution must be evaluated. In Sections 4 and 5, we detail the process of customer clustering and vehicle routing based on GIS data.

The distribution process under consideration in this paper has the following characteristics:

(1) One distribution center serves multiple customers.
(2) Thousands of customers are widely dispersed geographically.
(3) Various types of vehicles with different capacities are available.
(4) Customer demands are known.
(5) Order quantities are small, yet customers reorder frequently.
(6) The objective is to minimize the total distribution costs.
(7) The distribution center is remotely located from the delivery area.

The solution is derived following the two steps below:

(i) Divide the large-scale complex distribution network into several small-scale distribution areas subject to certain constraints to obtain an initial feasible solution of the two-stage method. Through clustering, we transform the multi-vehicle optimization problem into several traveling salesman problems (TSPs).
(ii) Design a heuristic algorithm to solve the TSPs one by one for each service area, resulting in quasi-optimal solution to the entire distribution area.

The solution scheme is summarized in Fig. 2, including the following steps:

(1) Analyze the current distribution process.
(2) Determine the measurement of the workload, which helps design a true balanced workload among regions.
(3) Calculate the shortest path between any two retail outlets using GIS.
(4) Divide the distribution area into sub-regions by implementing a GIS network, and ensure workload balance.

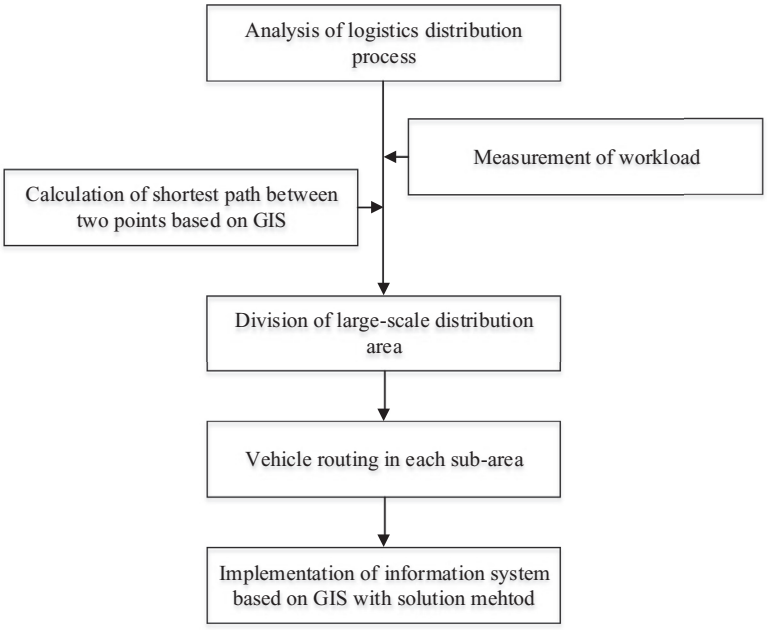

Fig. 2. Solution schema.