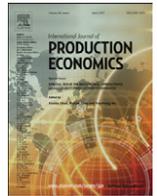


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A constraint programming approach to designing a newspaper distribution system

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ABSTRACT

This paper presents a constraint programming approach using a modeling language and CP optimizer to aid in the coordination of the production and delivery of multi-product newspapers to bulk delivery locations. The distribution problem is modeled as an open vehicle routing problem with time windows and zoning constraints. The use of a high level modeling language eliminates the need to develop custom low-level computer codes to solve the problem. The methodology is applied to the newspaper production and distribution problem in a major metropolitan area. Computational results are presented and show significant improvement relative to a previous metaheuristic approach using tabu search.

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1. Introduction

In this paper we present a constraint programming and optimization approach to integrate and coordinate the production and distribution of newspapers for a mid-sized newspaper publisher. The proposed methodology achieves consistently superior results compared to previous work involving a two-phase approach and a tabu search metaheuristic.

The newspaper industry needs to reduce logistics and operating costs more than ever because of intense competition from the Internet and in many instances, shrinking advertising revenue. Aside from the human resources and the materials utilized on a daily basis in producing newspapers, the physical distribution of the newspaper product is the highest day-to-day operational cost associated with the newspaper publishing business.

The distribution of the daily newspaper is becoming more and more of a concern because of the growth rate experienced in the pre-print segment of newspaper advertising and the need to provide subscribers with reliable delivery service. Pre-Print advertising has now become an integral part of the newspaper. In many instances, pre-print advertising is the preferred method of advertising for many large volume advertisers because of the different attributes available in a pre-print product. Because of the various sizes, weights, zones, distribution dates, and other variables, there is an incremental cost associated with handling the growing pre-print advertising products.

Newspaper companies, such as The Tulsa World, have a need to more effectively integrate the production, loading, and distribution of the newspaper and its associated advertising products. The complexity is no longer simply related to technology and equipment, but goes further in having the ability to adapt the newspaper's processes in production and distribution with the aid of logistics information to provide a more flexible, efficient, and customer-oriented operation. Successful newspapers understand that a core capability of their business is their distribution and logistics network and that it is necessary to identify where their performance can be improved in order to continue to be successful.

Over the years, as the pre-print advertising segment outgrew the manual capacity of packaging the various parts of the newspaper, investments in on-line inserting equipment were the trend with the pre-print advertising material being inserted into the newspaper as it was being produced. As the pre-print market continued to grow, many newspaper companies outgrew the efficiency of on-line inserting and changed their packaging deadlines in order to create pre-print packages a day or more before the distribution. The Tulsa World, as well as many other large newspaper companies, is now distributed in multiple packages containing the actual newspaper and the pre-print advertising material.

Because of the timing involved in the production of the newspaper, various editions and parts are produced with different content for a specific geographic zone creating a targeted advertising product. In comparison to the printing of the newspaper itself, the pre-print advertising material is delivered to a processing warehouse from a few days to a few weeks in advance of the

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packaging deadline. The pre-print materials are fed into an inserting machine to create zoned advertising packages based on the advertisers' geographic requirements. The packages are counted, stacked, labeled for zoning, tied in bundles, and are picked up just prior to the loading of the newspaper packages. (This is another example of product differentiation postponement in supply chains).

The delivery drivers are required to handle multiple packages with certain variations. The larger that the newspaper and the pre-print packages are, the larger the vehicle for transportation needs to be, and longer lead times are necessary for distribution.

Web based advertising continues to pose a formidable threat to newspapers and other media sources. As internet advertising revenues reach all time highs, massive changes in the world of advertising are expected. With more and more advertisers pushing for better targeting or zoning capabilities, The Tulsa World has been trying to creatively provide advertisers with solutions. Therefore, it is compelled to solve the problem as to how to manage the zoning of the growing pre-print advertising products more efficiently and cost effectively in order to remain competitive.

Chandra and Fisher (1994) conducted a computational study to investigate the value of coordinating production and distribution planning by comparing two approaches. In the first approach the production scheduling and vehicle routing problems are solved separately; in the second approach they are coordinated within a single model. They conclude that the reduction in total operating cost from coordination ranged from 3 to 20%. Their work is relevant to our investigation of newspaper logistics in that they considered the integration of production scheduling and vehicle routing.

Other approaches reported in the literature pertaining to the coordination or integration of logistics or supply chain activities has ranged from heuristics and metaheuristics to various types of optimization. Cohen and Lee (1988) studied the impact of various materials management strategies on the cost of production and service levels. Their work integrates the supply chain in terms of inventory distribution without considering their impact on physical distribution strategies. Ishii et al. (1988) tried to determine economic levels for the base stock and lead times for production and transportation in integrated production and distribution systems based on the pull type ordering system. Pyke and Cohen (1994) presented a model to represent an integrated production-distribution system comprised of a single station model of a factory, a stockpile of finished goods, and a single retailer and provide a near-optimization algorithm to solve the problem. Viswanathan and Mathur (1997) present a heuristic to determine replenishment policies that specify the delivery quantities and the vehicle routes to minimize the long-run average inventory and transportation costs for distribution systems with a central warehouse and many retailers that stock a number of different products. Carter and Ragsdale (2002) look at the pre-print advertising scheduling problem using a genetic algorithm (GA) approach. Their computational results using data from a mid-size newspaper show that the GA approach to developing schedules reduces the processing time associated with creating the pre-print packages. Van Buer et al. (1999) solved a medium newspaper production/distribution problem with various heuristic search algorithms and found that re-using trucks that have completed earlier routes is one way to achieve low-cost solutions. Russell et al. (2008) used a two-phase approach to the newspaper distribution problem. A generalized assignment problem was used to assign vehicle routes to clusters in order to satisfy a zone requirement that no route will cover more than two advertising zones. A tabu search metaheuristic was then employed to improve the routes. The two-phase approach achieved significant improvements in route efficiency compared to the existing distribution

system. In a subsequent simulation study, Chiang et al. (2009) examined the stochastic aspects of the newspaper production and distribution system and were able to achieve a higher level of customer service in terms of on-time delivery.

In this paper we approach the synchronization and coordination of newspaper production and delivery using a novel constraint programming formulation of the open vehicle routing problem adapted to the specific requirements of newspaper distribution.

2. Newspaper logistics

The methodology developed in this paper pertains specifically to The Tulsa World newspaper company. This midsize newspaper has a circulation of 135,000 Monday through Thursday, 164,000 on Friday, 150,000 on Saturday, and 193,000 on Sunday. In order to achieve its daily distribution, The Tulsa World utilizes 47 truck routes that deliver to the 818 carrier routes on a daily basis. These carrier routes cover more than 200 zip codes that are spread over various states.

2.1. Production

Newspapers are produced from midnight to 3:00 am the morning of distribution. The current production sequence is in order of distance from the plant. The state edition is produced first starting at 12:00 midnight followed by the city edition starting at 1:00 am. Each of the two production lines produces newspapers at a rate of 70,000 newspapers per hour. When combining the production rate of both production lines, a rate of 140,000 newspapers per hour can be achieved. Management's production strategy dictates that the state edition newspaper is produced at a rate of 70,000 newspapers per hour and the city edition newspaper be produced at a rate of 140,000 newspapers per hour.

2.2. Loading and sequencing

The portion of the distribution process examined in this study consists of truck routes that begin at the single distribution center at The Tulsa World production facility. The delivery trucks have a schedule detailing what time they are to arrive at the distribution center in order to load the pre-print and newspaper packages. They load in order of distance of travel from the distribution center to the zip codes on their route. The trucks load their pre-print packages at the pre-print loading dock before loading the actual newspaper at the newspaper loading dock. The entire circulation must be delivered to the delivery locations by 4:00 am and to the final consumer (i.e., household or business) by a 6:00 am delivery deadline.

The loading sequence is dependent on the production sequence. Because of the congestion created during the truck lineup for loading of the newspaper packages, only 2 to 3 of the available 8 loading docks are operating at any specific time. Trucks form a queue and position themselves in sequence along the 8 available loading docks without interrupting the flow from the two production lines. There are 2 loading docks operational for the state edition and 3 loading docks operational for the city edition.

The truck routes vary in distance as well as in circulation coverage. The drivers are independent distribution contractors and each truck does not always have the same capacity. Depending on vehicle capacity, the routes may have more or fewer deliveries along the route and may have a longer or smaller route as well. For some of the longer routes, there are relay routes

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