European Journal of Operational Research 243 (2015) 281–291

Contents lists available at ScienceDirect

European Journal of Operational Research

journal homepage: www.elsevier.com/locate/ejor

Innovative Applications of O.R.

Consolidating home meal delivery with limited operational disruption

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ARTICLE INFO

Article history:
Received 17 December 2012
Accepted 22 October 2014
Available online 10 November 2014

Keywords:
Transportation
OR in service industries
Integer programming
Heuristics

ABSTRACT

Non-profit organizations like the Meals On Wheels (MOW) association of America prepare and deliver meals, typically daily, to approximately one million homebound individuals in the United States alone. However, many MOW agencies are facing a steadily increasing number of clients requesting meal service without an increase in resources (either financial or human). One strategy for accommodating these requests is to deliver multiple (frozen) meals at a time and thus make fewer deliveries. However, many of the stakeholders (funders, volunteers, meal recipients) value the relationships that are developed by having a client receive daily deliveries from the same volunteer. Further, meal recipients may be concerned with the quality of food delivered in a frozen meal. In this paper, we develop a method for introducing consolidation into home meal delivery while minimizing operational disruptions and maintaining client satisfaction. With an extensive computational study, the savings associated with various levels and types of disruptions are detailed. The question of whether delivering frozen meals will enable an agency to both save money and deliver meals to a larger client base is also studied.

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1. Introduction

On a daily basis, non-profit organizations like the Meals On Wheels Association of America (MOW) deliver approximately one million meals throughout communities in the United States. Within each of these communities, many individuals aged 60 and older rely on government funded programs like MOW to meet their dietary needs for sustaining a healthy lifestyle. In addition to the aging population, MOW serves individuals who are incapable of sustaining themselves due to medical limitations. The assistance MOW provides helps their clients remain comfortable in their homes instead of requiring them to relocate to subsidized housing or nursing homes, either at personal or government expense. Individuals who wish to receive free or reduced-cost meal assistance must qualify, where the qualification process also determines the number of meals the individual should receive in a week. To deliver meals, MOW relies on a workforce comprised of both professionals and volunteers from each community, and routes between 800,000 and 1.2 million volunteers annually in the United States (Meals On Wheels Association of America, 2009).

MOW is seeing a steadily increasing demand for meals. From 1980 to 2002, the demand for meals in the United States increased by 290 percent. While contributions from private organizations and cost reduction efforts have helped MOW to increase the number of meals it delivers, their capabilities have not grown at the same rate as demand. As a result, MOW agencies are often forced to put some or all of the clients deliveries on a wait-list, although this is clearly undesirable. Similarly, MOW anticipates a significant increase in the number of seniors in America that face the threat of hunger (8.3. million in 2010, 9.5 million projected in 2025), and has stated that its vision is to end senior hunger by 2020 (Meals On Wheels Association of America, 2012).

One strategy for reducing costs and widening its client base that some MOW agencies have undertaken (while there is a national association, agencies are locally owned and operated) is to deliver frozen meals. An official from New York City stated, "for us it's really been about creating a more efficient system and not having anyone on a waiting list." That same official mentioned that by delivering frozen meals twice a week to 40 percent of its recipients they were able to reduce the number of professional drivers they paid from seventeen to three (Kelley, 2008). Similarly, delivering frozen meals has enabled MOW agencies to serve recipients in rural areas that, given limited driver resources, were too costly to reach on a daily basis (Gibson, 2004). By using frozen meals, MOW agencies find the benefits of consolidating deliveries that many other transportation providers have already discovered. However, while frozen meals allow for considerable cost savings, there are several operational challenges.

While the primary purpose of a MOW agency is to provide nutritious meals to those who cannot provide one for themselves, many

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http://dx.doi.org/10.1016/j.ejor.2014.10.045
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agencies and their supporters (both volunteers and funders) also see themselves as providing human interactions and relationships to those who may otherwise have little human contact (Kyle, 2012). As an example, many MOW agencies like to invoke the slogan "more than just a meal." Thus, while there are some clear efficiencies that can be gained by delivering frozen meals, some funding agencies that support MOW programs are reticent to support their delivery as they fear doing so will diminish the health monitoring capabilities of Meals On Wheels. Further, many have claimed that the quality of the frozen meals delivered is too inferior to hot meals (DeSio, 2008) to justify any savings realized.

Like major parcel delivery companies such as FedEx and UPS, MOW faces the problem of making home deliveries in large sized communities, containing demand at varied locations, and with delivery routes limited by vehicle capacity. However, while industry leaders in parcel delivery have the engineering and financial resources to invest in technology that handles these routing scenarios and to answer strategic what-if questions regarding how deliveries are made, many community based MOW agencies do not. Creating a good set of routes that are repeated on a daily basis can be difficult enough without an advanced routing algorithm. Consolidating deliveries on those routes may require the creation of a unique route for each day of service, putting an even greater strain on the MOW agency's limited operational resources.

This paper presents a methodology that MOW agencies can use to effectively introduce frozen meal delivery, which in turn allows for consolidation, into their delivery operations while limiting operational disruption and client dissatisfaction. Transportation costs incurred by executing daily routes with and without consolidation are compared in an extensive computational analysis that details the operational disruptions and quality of service metrics that most impact these costs. It is found that the impact on savings from consolidation when operational disruptions are prohibited is much smaller than when high standards for quality of service metrics are enforced. However, even with high quality of service standards, the savings are significant, with transportation costs often reduced by more than 20 percent. For MOW agencies that are operating at such tight margins, those savings can have a very significant impact. One of the primary objectives of MOW agencies is to serve meals to as many individuals as possible. Thus the second part of the computational study focuses on whether consolidation can increase the number of meals delivered while still reducing transportation costs. The study also examines how operational disruptions impact the potential for consolidation to both increase access and reduce costs.

While this work is presented in the context of its inspiration, Meals On Wheels, the methodology and results presented are pertinent to any organization that wishes to quantify the tradeoffs between consolidating deliveries and maintaining high levels of customer service, such as a mail delivery or LTL carrier. Various initiatives to reduce operating costs of the United States Postal Service (USPS) have been proposed, in particular the elimination of Saturday delivery (Hicks, 2013). However, reducing operating costs through the elimination or consolidation of service days without upsetting customers is likely to be very difficult for the USPS. The methodology presented here allows for operational consolidation while minimizing the change from current routing (likely to be important for any postal carrier), maintaining a consistent client-provider relationship (important for both the carrier and customer), and limiting the number of days between service (important for the customer). Further, it shows that the USPS may be afforded some flexibility in selecting how to reduce service, as eliminating Saturday delivery may be less attractive since it leaves two consecutive days without service. Eliminating service on other days of the week would have no difference in terms of routing, while limiting the number of days between service. As the USPS continues to explore various possibilities for service consolidation, the methodology developed here is certainly applicable.

2. Literature review

Some of the earliest work on the home meal delivery problem was presented in Bartholdi, Platzman, Collins, and Warden (1983), which used space-filling curves as the basis of a system that could be implemented on two rolodex cards. While this work is fundamentally different from ours, the emphasis on operational ease is shared. In the setting of this problem, clients currently receive hot meals five days a week and the agency has an established set of delivery routes that are executed daily. Based on those routes, the approach presented in this paper can maintain consistency with historical operations by ensuring that a client remains on the same route as before, and that clients are seen in the same order.

Introducing consolidation into daily delivery routes is reminiscent of vendor-managed inventory or the Inventory Routing Problem (Andersson, Hoff, Christiansen, Hasle, & Løkketangen, 2010); (Campbell, Clarke, Kleywegt, & Savelsbergh, 1998). However, we consider constraints that have not been included in the inventory routing problem. For example, this approach can support fixed routes (Beasley, 1984; Erera, Savelsbergh, & Uyar, 2009) by serving the clients in the same order on every route. Such a restriction can have many operational advantages, including making it easier to synchronize the meal preparation and vehicle loading process. This problem is inherently periodic and thus shares characteristics with the Periodic Vehicle Routing Problem (PVRP). A review of the PVRP may be found in Francis, Smilowitz, and Tzur (2008), with numerous algorithms developed to solve this problem recently, including the use of variable neighborhood search (Hemmelmayr, Doerner, & Hartl, 2009), a hybrid genetic algorithm (Vidal, Crainic, Gendreau, Lahrichi, & Rei, 2012), a set covering heuristic (Cacchiani, Hemmelmayr, & Tricoire, 2014) and an ant colony optimization model (Yu & Yang, 2011). However, like the work on the PVRP with Service Choice (Francis & Smilowitz, 2006; Francis, Smilowitz, & Tzur, 2006, 2007), the number of times an individual is visited is not an input to our model but a decision variable, allowing for additional flexibility in the delivery plan. We further extend the flexibility enabled by the PVRP with Service Choice to allow for multiple deliveries to be made in one visit, while maintaining consistency of service.

Another advantage of executing the same delivery route every day is that such a delivery system is inherently equitable for meal recipients. MOW is concerned with ensuring that its clients are treated equitably and thus the methodology presented in this paper maintains equity by ensuring that when one client receives a hot meal, all do. Equity is also considered in the distribution of supplies in a disaster relief setting in Huang, Smilowitz, and Balcik (2012), Tzeng, Cheng, and Huang (2007) and a review of how equity has been considered in other routing problems that appear in the nonprofit or public sector may be found in Balcik, Iravani, and Smilowitz (2010). To the best of our knowledge there has been no work done on Inventory Routing Problems that consider equity issues.

With equity in mind, this approach can also enforce various quality of service-type metrics. For an agency that is concerned with the quality disparity between frozen and hot meals, this approach can ensure that each client receives at least a minimum number of hot meals. For an agency that wishes to maintain the relationships their drivers have with clients this approach can enforce a maximum number of days between visits and that a client is always visited by the same driver. Quality-of-service metrics were also studied in the context of inventory routing in Coelho, Cordeau, and Laporte (2012), including driver consistency where each customer is seen by one driver. To help foster relationships between clients and delivery persons we also enforce such a rule; the benefits of such a delivery system are discussed in Smilowitz, Nowak, and Jiang (2013).

To determine the potential efficiencies associated with delivering frozen meals, the problem of introducing consolidation is formulated as a mixed integer program (MIP). Different variants of this MIP are

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