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Efficient frontiers in a frontier state: Viability of mobile dentistry services in rural areas

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ABSTRACT

This study investigates the implications of adding mobile dentistry services to a community health center (CHC) in a rural area. CHCs are not-for-profit healthcare organizations which provide comprehensive primary care services to patients in the US, primarily for under-served and uninsured populations. We estimate the demand for the service in a five-county region in southwestern Montana, USA and work with stakeholders to determine a set of potential service locations. A mixed-integer optimization model is formulated to determine the frequency of stops in each location over a finite (six month) planning horizon with the goal of improving accessibility and availability of dental services while maintaining financial sustainability of the CHC. The financial considerations and social impact of offering a mobile dentistry service in southwestern Montana are assessed. Computational results based on a case study demonstrate the challenges facing mobile dentistry operations to increase access to under-served populations in a financially viable manner. Hybrid solutions, in which care is offered at a mix of fixed locations and mobile locations, appear to best balance the objectives of financial sustainability and expanded access to care.

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1. Introduction

Dental health is essential for overall general health and well-being (Davis et al., 2010). The Surgeon General's 2000 report notes that oral infections are associated with increased risk of diabetes, heart disease, and stroke (US Department of Health and Human Services, 2000). In addition to the connection between oral health and systemic health, it has been established that oral disorders have an adverse effect on quality of life and economic productivity (Hollister & Weintraub, 1993).

Access to dental care is a major issue for those in rural areas in the US, where the closest dental office may be far from a person's home (US Department of Health and Human Services, 2004). This dental access problem is magnified for people who do not have dependable travel options (e.g., in areas without public transportation people may need to borrow a car or obtain a ride from a family or friend). There are also financial barriers to dental care access, since many people without dental insurance cannot afford to pay for care out-of-pocket. Medicaid is a public insurance

program for low-income people in the US that includes coverage for dental services in some states (Medicaid.gov, 2016). However, Medicaid-enrolled patients may not be able to easily find a dental provider willing to accept their public insurance. A major access point for such patients is at community health centers (CHCs), which are not-for-profit healthcare organizations providing comprehensive primary care services to people including those who are medically under-served and uninsured. However, especially in rural areas, there can still be a large distance from a person's home to the nearest CHC.

Mobile dentistry has emerged as an alternative service delivery method to counteract these access problems. Mobile dentistry involves dentists, dental hygienists, and dental assistants traveling in vans or trailers with onboard dental equipment to serve patients at locations near the patients' homes. A challenge for organizations considering mobile dentistry as a viable business model is the balancing act of extending services to as many people as possible in a financially sustainable way. Scholarly discourse has not adequately addressed this problem.

In this paper, we develop a data-driven, optimization-based approach to explore the potential for a rural CHC to add mobile dentistry services, and we apply the model to a five-county region in southwestern Montana. We consider the network design of the mobile dentistry operation, determining the location of mobile

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dentistry stops, the frequency of visits, and the composition of the dental care team over a six-month planning horizon. We model the mobile dentistry network design problem (MDNDP) as a mixed-integer program, with the goal of improving dental care accessibility and availability for under-served populations while considering the financial sustainability of the service.

This paper makes several contributions to research on mobile dentistry. First, we use a community-based operations research (CBOR) approach to identify the problem and formulate the MDNDP as a mixed-integer program to improve accessibility and availability of dental services while maintaining financial sustainability. Next, we use a data-driven, optimization-based methodology to answer questions regarding how a local CHC could improve their rural dental mission in an economically sustainable fashion. Elsewhere, this research could be generalized and leveraged by healthcare organizations in rural regions to understand the trade-offs regarding the operation of mobile healthcare facilities providing other types of service (e.g., optometry).

The remainder of this paper is structured as follows. The next section presents a literature review related to rural dental service access, mobile dentistry, and mobile facility routing more generally. Section 3 illustrates the research process used to identify and formulate the model, and presents the model. Section 4 discusses the application of our model to a case study in southwestern Montana and presents the results, followed by a discussion in Section 5. Section 6 presents concluding remarks.

2. Problem description

2.1. Dental needs in rural areas

Skillman, Doescher, Mouradian, and Brunson (2010) describe issues facing rural populations which include lower utilization of dental care services, and higher rates of cavities and permanent tooth loss compared to urban populations. The authors suggest that reasons for these differences include the lower rate of dental insurance coverage, less access to dental services, and higher poverty among those living in rural areas. The US Department of Health and Human Services (2004) identifies several factors contributing to access problems for dental services in rural areas, including: lack of fluorinated water supplies, geographic isolation, inadequate transportation, higher rates of poverty, larger percentage of elderly people, low rates of dental insurance, acute provider shortages, and difficulty finding providers willing to treat Medicaid-enrolled patients. Kimminau and Wellever (2011) introduce the concept of “Dental Service Area Deserts” to describe rural areas that don’t have coverage from a primary care dental office.

These problems in rural areas are intensified for the elderly, as older adults in rural areas have less favorable oral health and are less likely to be insured than their urban counterparts (Vargas, Yellowitz, & Hayes, 2003). Traveling for services may be especially difficult for some populations, including the elderly. Access to dental care is a prevailing problem for 1.75 million people in long-term care facilities in the US (Guay, 2005).

Mobile dentistry has emerged as an approach to address these access problems. For example, Apple Tree Dental¹ is a non-profit organization in Minnesota that operates a mobile dentistry service for group homes, schools and other locations. Apple Tree Dental’s business model involves bringing portable equipment to locations, such as childcare centers, and temporarily transforming them into dental offices.

Another approach is for dentists to travel in vans or trailers with onboard dental equipment to serve patients. An example of

this type of operation is the Ronald McDonald Care Mobile (RMCM) that operates out of Billings, Montana and receives financial support from St. Vincent’s Healthcare Foundation (Ronald McDonald Care Mobile, 2016). RMCM operates a 40-foot camper plus truck cab with two chairs, its dental operations are staffed by a dentist and a dental hygienist. It currently serves 43 schools for dental screenings, and visits approximately 25 towns for pediatric clinical work. According to their dental hygienist, RMCM visits one location each day they operate, operating up to two days per week with a maximum trip distance of 120 miles (M. Utley, personal communication, May 24, 2016). While it brings tremendous increase in access for pediatric patients throughout Montana, RMCM would not be financially sustainable without charitable donations and grant funding.

Another example of mobile dentistry in Montana is the operation at Granite County Medical Center (GCMC) (Briggeman, 2013). GCMC was able to purchase a mobile dental van due to winning a grant from the Health Services and Resources Administration in 2010. However, the mobile operation was not sustainable and was discontinued after one year. Despite many examples available of mobile dentistry being supported by grants, it is an open question of under what conditions mobile dental operations for under-served populations in rural areas can be financially sustainable on their own.

2.2. Academic literature on mobile facility location

There is an extensive stream of research literature on mobile facility location. Hodgson, Laporte, and Semet (1998) propose a covering tour model to develop routes for a mobile health care facility in Ghana, Africa. Lei, Lin, and Miao (2014) examine a mobile facility routing and scheduling problem under stochastic demand and formulate the problem as a two-stage stochastic programming model. The authors mention applications including trucks equipped with cellular base stations to serve areas where cell networks are disrupted, and fast food service from vans. Lei, Lin, and Miao (2016) develop a two-stage robust optimization approach for mobile facility fleet sizing and routing under demand uncertainty using a network flow formulation. The models from the previous three papers mentioned do not include setup times, which is a significant operational constraint for the mobile dentistry problem discussed in this paper. In a related paper that does include setup times, Doerner, Focke, and Gutjahr (2007) develop tours for mobile healthcare facilities in a developing country by modeling the problem as a variant of a vehicle routing problem. However, the mobile dentistry problem studied in this paper involves longer setup times than the ten minute setup assumed by Doerner et al. (2007). Other mobile dentistry operations in Montana cite setup times of around 30–45 minutes, with similar breakdown times (M. Utley, personal communication, May 24, 2016). Therefore, for the application considered in this paper, it is assumed to be only practical to visit one location on a given day, leaving from and returning to the home location each day, which eliminates the need for inclusion of routing constraints. Other distinctions of the current paper that have not been addressed in the literature are the consideration of financial sustainability and equity of service across locations for mobile dentistry.

2.3. Approaching the problem using a CBOR approach

This research problem falls squarely within the realm of CBOR as it highlights “the needs and concerns of disadvantaged human stakeholders” (Johnson & Smilowitz, 2012). Johnson and Smilowitz (2012) remark that the defining characteristics to distinguish CBOR from other areas of public-sector OR are the focus on human stakeholders, disadvantaged populations, and community-level

¹ Apple Tree Dental mobile dentistry website: <http://www.appletreedental.org/services/mobile-dental-care/>.

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