Vehicle routing approach in allocating mobile health service network – Opportunities of reaching peripheral populations in Northern Finland

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Abstract

Health service accessibility in Northern Finland is partly poor due to sparse population structure. Accessibility of non-urgent primary health services could potentially be enhanced by providing mobile health services. In this preliminary study scenario, GIS and accessibility analyses are applied to design service routes and locate service points of mobile health care units in Northern Finland. The key methods applied are Location allocation and Vehicle routing problem analyses. Spatial data consists of population grid cells, population predictions, locations of health centres and road network. Key finding of this study is that peripheral towns and villages of Northern Finland could be effectively reached weekly by two mobile service units. By four units 29 000 people would gain some benefit in accessibility of health services, and 3000 would reach services much better. Thus, mobile service network would distinctly benefit a small share of population, but in general, accessibility benefits to large population would be small.

Keywords: accessibility, allocation, health care, mobile service, Northern Finland, vehicle routing problem

1 Introduction

Peripheral areas of Northern Finland are suffering from population ageing and outmigration. Distances to health services are very long in some of the areas. Moreover, there is an economic pressure for rationalizations of services, which may cause closures of health centres and result in more sparse service network in the future. New openings for maintaining and developing service network in the peripheral areas would benefit the populations in these regions.

Aim of this preliminary study is to examine how much the peripheral service network could be enhanced by providing health care with mobile services. Study has three subtasks. 1. What would be the potential service sites (distant villages and towns) of mobile health service unit? 2. How well could the mobile health service network reach population of peripheral areas? 3. What would be the effect of the mobile health services to accessibility, in relation to health centre network?

2 Data and methods

A computational scenario based on GIS and accessibility analyses is applied to design service routes and locate service points of mobile health care unit. Spatial data consists of 1×1 km population grid cells (of Statistics Finland), villages and towns (of Finnish Environment Institute), health centres (National Institute for Health and Welfare) and Digiroad data of road network including accurate road geometry and speed limit data for travel time estimation (Finnish Transport agency).

Successful service route generation has a key role in the analysis. All routing in this study is based on ArcGIS vehicle routing problem (VRP) method [1]. In general, least cost path formulation applied in route generation has its background in graph theory and in Dikstra's algorithm [2]. Instead of finding optimal route for one vehicle between origin and destination [3], the study applies routing designed for routing several vehicles accessing several destinations with differing weights and aiming to minimise travel cost and maximise sum of accessed nodal weights. More specifically, the analysis for VRP determines a set of routes, each performed by a single vehicle which starts and ends at its own depot, fulfilling all the requirements of the customers and minimizing transport costs [4]. Thus, VRP computationally is a superset of the classical traveling salesman problem (TSP), in which set of stops is organized optimally. As there is no applicable method to find the precise optimal solution heuristics are applied to find the most suitable one.

3 Analysis and results

In the computation, a set of following presumptions were used. Depots of four mobile health service units are located in major health centres (or hospitals) of the northernmost Finland, as they already have better service level with round-the-clock emergency services. Potential mobile health care service nodes are towns and villages that are without health service units or have units with very low utilization rate. Service routes are driven weekly. Each service stop takes 1 hour and 30 minutes and total time of each route is 8 hours. Van size vehicle is used (max speed is 100 km/h).

GIS analyses were carried out in five stages. First, location-allocation (minimum impedance) analysis was used to select health centres potentially under a risk of closure. Official population prediction for year 2025 and population structure of postal code areas was used for demand [5]. Second, potential target group of population (1×1 km grid cells) for mobile health services was selected from areas that situated over 30 km from nearest remaining health centre. Third, the target population was allocated to villages and towns that located over 30 km from health centres. If villages and towns had a distance less than 10 km, the one having the most accessible location in relation to population was selected. Fourth, service routes were established to cover the most effective set of 69 service nodes in relation to population (Fig 1a). Four locations were included as compulsory targets due to their extreme peripherality. As a result, 44 nodes are reached by mobile health services, and 25 nodes remain outside the service network. Fifth accessibility improvements of the mobile health service network were considered (Fig 1b).

Key finding is that peripheral towns and villages of Northern Finland could be effectively reached weekly by two mobile service units. On the basis of population grid cell data and closest facility accessibility analysis, with four mobile units 29 000 people would gain a slight benefit in accessibility of health services, and about 3000 would reach the services by 100 km shorter back and forth travel. Cumulative accessibility and its change are presented in the figure 2. Mobile health service network would thus benefit a small share of population substantially, but for the remainder the accessibility benefits would be small.

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Figure 1a (left): Allocation of mobile health service network. 1b (right): Effect of mobile health services to accessibility of health care. Change in accessibility is expressed as one-way travel length to closest health service site, when mobile health service network complements the health centre network.

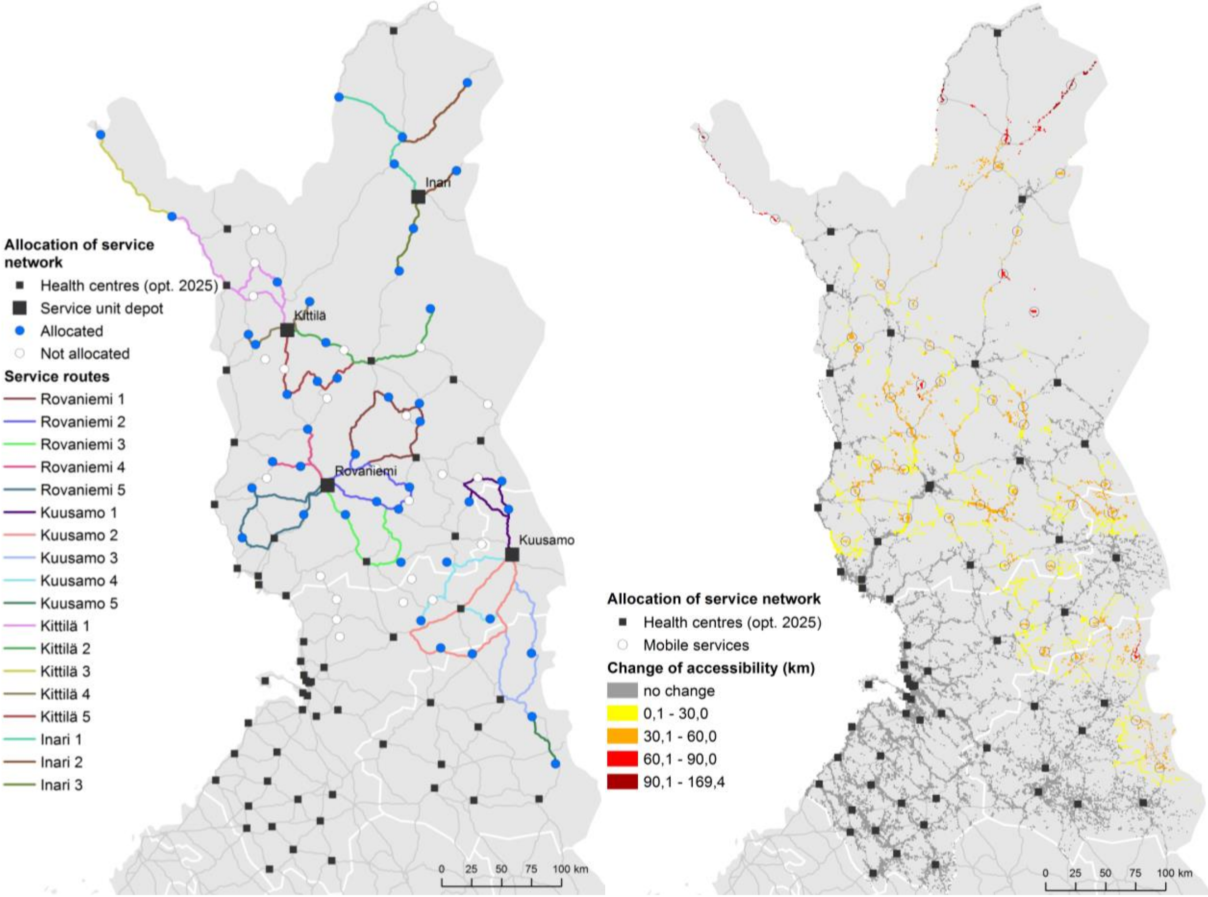

Figure 2: Potential effect of mobile health services to health care accessibility in Northern Finland within the population (29 000 people) benefitting the mobile service network. (x = km, y = %).