Available online at www.sciencedirect.com

ScienceDirect

Transportation Research Procedia 71 (2023) 109–116

Transportation Research Procedia

www.elsevier.com/locate/procedia

XV Conference on Transport Engineering, CIT2023

Health Care Logistics in Depopulated Mountainous Areas: the case of Lleida's Pyrenees

Cristian Castillo[a], Laura Calvet[b,*], Javier Panadero[c], Eduard J. Alvarez-Palau[a], Marta Viu Roig[a], Angel A. Juan[d]

[a] *Faculty of Business and Economics, Universitat Oberta de Catalunya, 08035 Barcelona, Spain*

[b] *Department of Telecommunications and Systems Engineering, Autonomous University of Barcelona, 08202 Sabadell, Spain*

[c] *Department of Management, Universitat Politècnica de Catalunya—BarcelonaTech, 08028 Barcelona, Spain*

[d] *Dept. of Applied Statistics and Operations Research Universitat Politècnica de València Plaza Ferrandiz-Carbonell Alcoy, 03801, Spain*

Abstract

For many years, European demography is experiencing two worrying phenomena: aging and migrations of young people towards urban agglomerations. Rural areas are becoming depopulated, and many public services are becoming unsustainable. Health care assistance is one of those services called into question, specially for elder people living in small towns without access to primary care. Fortunately, technological development allows us to improve this situation. First by obtaining, storing, and analysing all kinds of data related to the patient's health. Second, by developing intelligent algorithms that optimize the available resources to provide a better service. This article studies the level of coverage of primary care centres in the Pyrenees of Lleida, Spain, and proposes the use of an optimization algorithm for an efficient and effective design of routes that allow primary health care professionals to move from a medical centre to the homes of patients who require a visit. To illustrate the use of this methodology, we present a study focused on Bausen, a depopulated municipality in the Aran Valley, close to the French border.

Keywords: Health Care Logistics; Coverage of Primary Care Centres; Depopulation of Rural Areas; Optimization

1. Introduction

In recent decades the differences between the services available in rural and urban areas such as education, leisure, economic opportunities or health services have widened (Singh and Siahpush, 2014). In the case of the autonomous community of Catalonia (Spain), despite advances in the health system, health care in rural areas is still deficient compared to urban areas. This problem is due to several factors such as the lack of health professionals in these areas, the lack of access to specialised services and the ageing of the population.

* Corresponding author.
E-mail address: laura.calvet.linan@uab.cat

2352-1465
10.1016/j.trpro.2023.11.064

According to data from the Statistical Institute of Catalonia (IDESCAT)[1], in 2020, 72.7% of Catalonia's municipalities will be classified as rural areas and these will account for 8.7% of the population. If we look at the rate of doctors per inhabitant in rural areas, it is significantly lower than in large urban areas. Specifically, urban areas have a rate of 3.7 doctors per 1,000 inhabitants, while in rural areas this rate is only 2.2 doctors per 1,000 inhabitants. The IDESCAT also shows that 27.3% of the population in rural areas of Catalonia is over 65 years old compared to 20.3% of the urban population, resulting in greater dependence on health coverage in these municipalities (Nelson and Stover Gingerich, 2010). If we place the focus on the province of Lleida[2] (Catalonia), of the 231 municipalities that make up the area, 39 (16.88%) have a primary care centre, 191 (82.69%) have a local health clinic - which on most occasions does not offer continuous care every day of the week with extended opening hours - and we find one municipality (0.43%), Abella de la Conca, which has no health centre at all. This situation hinders the health coverage of the population of these areas, which in most cases must travel to other municipalities with continuous care, and generates the subsequent increase in their costs by having to travel by their own means (Salas and López, 2002). If we add to this the difficulty for the elderly to travel in rural mountain areas, with long journeys on narrow – sometimes winding – roads and tracks, the need to find solutions to provide healthcare coverage for this vulnerable population becomes evident.

Our study presents a novel and original route planning that allows primary care professionals to go to the municipalities located in the Lleida Pyrenees with a home health care vehicle to attend patients who require a home visit. In order to illustrate the use of this route planning, we will focus on the case study of the municipality of Bausen. This municipality has a population of 68 inhabitants and a local clinic that is currently closed and not open to the public. Thus, our route management model will show the planning of health care to several municipalities - including Bausen - in order to identify the benefits of our proposal in relation to the current situation.

The rest of the article is structured as follows. Section 2 reviews related work. Subsequently, a formal description of the problem and the methodology used are explained in Sections 3 and 4, respectively. The case study is presented in Section 5, while the analysis of the results and a discussion are provided in Section 6. Finally, Section 7 presents the main conclusions of the study and identifies lines of future research.

2. Literature Review

Rural depopulation is a global phenomenon affecting many geographical areas. This process leads to a reduction of the population in rural areas and, consequently, a decrease in the supply of services in rural areas, including health services (Pinilla and Sáez, 2017). The lower supply of healthcare in rural areas – compared to that offered in large cities – has negative consequences on the health of people living in these areas. This is exacerbated by the fact that the majority of the rural population is made up of people over 60 years of age, who are more likely to need health services (Cheng et al., 2020). Before the arrival of COVID-19, in the autonomous community of Catalonia (Spain), almost a quarter of the municipalities in the territory were at risk of depopulation according to the study by Aldomà i Buixadé et al. (2022). According to the same study, the province of Lleida is one of the most affected – with 89 of its 231 municipalities in a critical situation of depopulation – with the Alt Pirineu region (mountainous area) being one of the most affected. If we add to this situation the current territorial distribution of primary care centres in the province of Lleida, in which 82.69% do not have a centre with continuous health care, health care in this area becomes a real problem for the population that must be tackled from different perspectives.

2.1. Alternative to face-to-face health care: Video-medical consultations

One of the alternatives that is beginning to be implemented in rural areas with low health coverage is video-consultation. According to the World Health Organisation (WHO), video-medical consultation involves the use of technology to provide health care outside traditional health facilities. Video-medical consultation is a good alternative in cases where there are insufficient staff or resources to provide continuous healthcare. The geographical dispersion of rural areas, especially in mountainous areas, such as the province of Lleida, is an obstacle for the care of residents

[1] https://www.idescat.cat/novetats/?id=4310&lang=es

[2] https://www.sanidad.gob.es/estadEstudios/estadisticas/sisInfSanSNS/ofertaRecursos.htm

(Toledo et al., 2012). Video-consultation substantially increases the quality of care for residents in rural areas and also improves communication between primary care and specialist staff (Norman, 2006; Wesson and Kupperschmidt, 2013). Video-consultation becomes a very useful tool for elderly people with reduced mobility who would find it difficult to travel to a primary care centre by their own means (Wesson and Kupperschmidt, 2013). Moreover, the technology used in video-consultation is fully accessible to the general public and very inexpensive – as any smartphone, computer or tablet can serve as a device to carry it out – a factor that increases its potential as a real alternative to face-to-face medical consultation (Qidwai et al., 2008). However, one of its main handicaps is that, despite being a tool accessible to the general public, it is a barrier to entry for the elderly population, which is precisely the most representative population in rural areas (Johansson et al., 2014). For this reason, there is a need to continue exploring new alternatives that complement video-consultation and offer greater health coverage in rural areas.

2.2. Home health care routing and scheduling: A complement to video-medical consultation

Home healthcare is one of the fastest growing sectors in recent years, largely due to the geographical challenges faced by most countries due to the depopulation of their rural areas. Home healthcare is the transfer of the same service from a doctor's office to the patient's home. This provides an opportunity for people living in rural areas who would otherwise be excluded from the health services offered in large cities (Landers et al., 2016). However, in order for the logistics associated with these home visits by health centres to be optimal, route planning is needed that takes into account, as a whole, all the visits that need to be made in the same geographical area. The optimal planning of home healthcare routes is complex and represents a constant challenge, since decisive decisions must be made regarding work shifts, the allocation of specialised staff and the routing itself (Gutiérrez et al., 2013). In addition, the time variable plays a fundamental role in this type of route planning, as certain routine treatments have a maximum timeframe for completion. For example, the provision of insulin to elderly people with reduced mobility (Gutiérrez et al., 2013). Therefore, when planning routes, it is necessary to consider all the casuistry of the patients to be attended, and thus establish an order of priority that will condition travel distances, work time and quality of service (Fikar and Hirsch, 2017). Another important aspect to consider when planning routes for home care is the incorporation of sustainable vehicles, such as electric vehicles. In this way, the three pillars – people, planet and profit – of sustainability theory (Elkington, 1998) would be included in route planning: economic factors, optimising the route to make the shortest possible journey; ecological factors, using clean energy vehicles so as not to emit polluting gases; and social factors, providing health coverage to vulnerable people living in rural areas (Assembly, 2005).

3. Description of the Problem

This section provides a formal description of the routing problem, which is related to home healthcare services, tackled in this paper. The problem is called Team Orienteering Problem (TOP) (Martins et al., 2021) and is formally described next. Let there be an undirected and complete graph $G = (V, E)$, where: (i) $V = \{0, 1, 2, \dots, n\}$ are the depot node 0 and a set of n user nodes to be visited; and (ii) $E = \{(i, j)|i, j \text{ in } V \text{ and } i <> j\}$ represents the set of edges that connect every pair of nodes in V. Given an edge (i, j), traversing it has a distance- or time-based cost $c_{ij} = c_{ji} \geq 0$. Let W represent the working days of a week, $W = \{Monday, Tuesday, \dots, Friday\}$. Visiting a user node i in $V \sim 0$ has an associated reward $r_{id} \geq 0$, which represents the urgency level of visiting user i in $V \sim 0$ in a given day d. Thus, a user that requires an urgent visit will have associated a very high reward during day d, while users with milder symptoms will have a lower, but still positive, reward. These rewards might change each day. For example, if a user has not been visited during a day d, then the reward on day $d+1$ increases. In contrast, if a user has been visited during day d, then the reward on day $d + 1$ decreases. In this work we assume that the variations of these rewards can be modeled as a function $f(i, d + 1) = f(i, d + 1, r_{id}, x_{id})$, where $x_{id} = 1$ if user node i was visited on day d and 0 otherwise.

The problem describes a multi-period scenario in which both the list of users to be visited at home and the associated routes for each working day in W are defined before the first day. The goal of the TOP is to maximize the total reward collected over the week. There are some constraints to consider: (i) all urgent visits in a day d are covered; (ii) for each day d, the total cost of any route does not exceed a threshold C, which can represent the maximum number of working hours per day or the maximum time that one driver can drive.

4. Methodology

The methodology used to address the problem described in the previous section is a constructive heuristic presented in Panadero et al. (2021). This heuristic relies on savings (Clarke and Wright, 1964) to design routes, which are computed based on both the reward and the savings in time. Initially, a dummy solution is built, which considers one route for each user. In each of these routes a vehicle leaves the depot, visits the user node and returns to the depot. The next step consists in computing the savings associated with each edge connecting two users. The savings are computed as the benefits obtained by visiting both users in the same route instead of using two different routes. Thus, for an edge (i, j), the savings s^*_{ij}, are computed as $s^*_{ij} = \alpha \cdot s_{ij} + (1-\alpha) \cdot (u_i + u_j)$, where α $(0 \leq \alpha \leq 1)$ is a parameter of the algorithm. The savings take into account time-based savings, $s_{ij} = t_{i0} + t_{0j} - t_{ij}$, and the rewards, $u_i + u_j$. The travel times matrix is symmetric, i.e., the savings do not depend on the direction in which the edge is traversed ($s^*_{ij} = s^*_{ji}$). The next step is to sort the list of edges from higher to lower savings. An iterative merging process starts: in each iteration, the heuristic selects the edge at the top and, provided no constraint is violated, the two routes connected by the edge selected are merged into a new route. In the last step the heuristic keeps the routes with the highest rewards, being the number of routes equal to the size of the vehicle fleet.

The algorithm has been implemented in Python 3.10.7[3] and the OSRM software[4] has been used to create a traveling time matrix, which constitutes the input of the algorithm.

5. Case Study

To illustrate the concepts introduced in this paper, we have designed a realistic case study based in the province of Lleida, specifically in the municipality of Bausen. This mountain municipality, considered to be part of unpopulated Catalonia, has only 68 inhabitants and the local primary care clinic is currently closed to the public. This is a serious problem for the inhabitants of the municipality who see their health needs unattended and forced to go to a health centre outside their municipality. In response to this problem, we propose a model of routes that covers a total of 198 municipalities in the province of Lleida - including the municipality of Buasen and others in a situation of health care deficiency - so that health personnel can make home visits. In order to plan the routes, we first selected a starting health centre (hub of origin) from which all the outings would be made. To select this centre, network centrality techniques were used, and the centre chosen was the one in the municipality of El Pla de Sant Tirs (Lleida). Therefore, a single centre of origin was proposed in order to optimise the routes and plan home health care every day of the week according to the number of patients to be visited. The routes had to comply with the following modelling conditions, which were fully parameterisable: (1) 8 hours of working time for the medical staff in each vehicle; (2) 10 minutes of consultation time in each home; (3) a fleet of 3, 4 and 5 vehicles for the simulation; (4) a consultation planning horizon of 5 days (Monday to Friday); (5) the patients to be visited are assigned a priority number from 1 to 5 (the higher the priority, the earlier in the week they should be visited); and (6) visiting a patient has a reward.

6. Analysis of Results and Discussion

To obtain our results, we applied the route planning and management model to the case study described in the previous section. We performed different combinations of vehicle fleets for home health care and compared their route management. We evaluated three types of fleets: 3, 4 and 5 vehicles, and to calculate transport costs we considered the use of electric vehicles to reduce the environmental impact. The cost of using these vehicles was 0.43 €/km (Gerssen-Gondelach and Faaij, 2012). Table 1 shows an example of route planning and compares the reward obtained as a function of the number of patients visited, the total time spent (which includes travel time and consultation time) and the estimated total cost in relation to the kilometers travelled (€/km) on each of the home care routes. Figure 1 graphically presents the total time in minutes needed to perform home care as a function of fleet size, while Figure 2 shows the ratio euros/kilometer per day in the management of routes.

[3] www.python.org
[4] https://project-osrm.org/

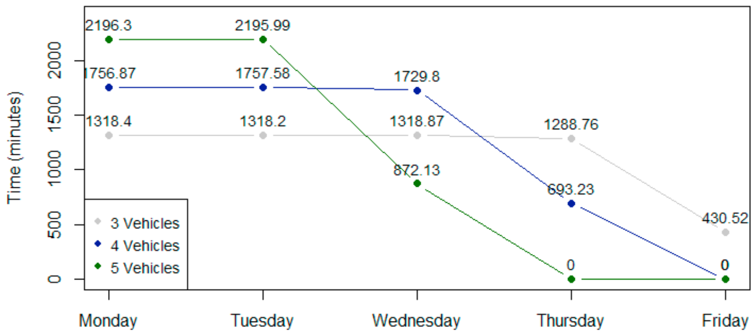

Fig. 1: Comparison of the total time spent per day in the management of routes with 3, 4 and 5 vehicles to provide health coverage.

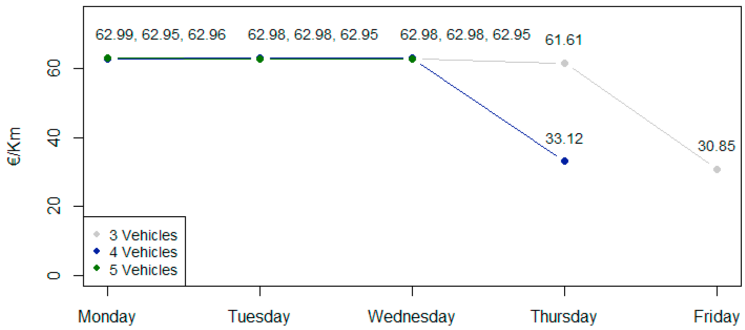

Fig. 2: Comparison of the ratio euros/kilometer per day in the management of routes with 3, 4 and 5 vehicles to provide health coverage.

Figures 1 and 2 show how, with a fleet of three vehicles, we would be able to carry out all the scheduled home health care services in five days. Whereas, using a fleet of five vehicles, we would be able to carry out all the scheduled health care visits in just three days. However, in order to check the usefulness of the proposed route planning model, it is necessary to compare our results with the current real scenario of home health care in which health centre staff travel to each user's home on a first-come, first-served basis and without the coordination of routes as proposed in our model. Thus, we carried out the comparison taking into account the number of home visits that should be made on the first day of the week (Monday), taking into account the current care scenario and our route management model for a fleet of three vehicles. In total, 43 municipalities had to be visited, including our case study municipality Bausen.

In order to take into account the current model and compare it with our model, for each of the municipalities to be visited we consulted the health centre that corresponded to it and whether it was currently operational or not. In the event that the municipality had a clinic with limited public attention, we considered the nearest health centre that would provide health care for the current model. Thus, in Figure 3 we can see a comparative map of route management for the current scenario in which visits are not coordinated and for a case of application of our model for a fleet of three vehicles.

Table 1: Results for home visits with 3, 4, and 5 vehicles, respectively.

	Monday				Tuesday				Wednesday				Thursday				Friday			
	Reward	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km
V1	960	439.15	146.38	62.94	650	438.93	146.65	63.06	560	439.60	146.53	63.01	190	437.23	145.74	62.67	60	290.47	96.82	41.63
V2	760	439.95	146.65	63.06	590	439.57	146.52	63.01	370	439.75	146.58	63.03	190	429.85	143.28	61.61	10	140.05	46.68	20.07
V3	680	439.30	146.43	62.97	540	439.70	146.57	63.02	280	439.52	146.51	29.30	130	421.68	140.56	60.44	-	-	-	-
Avg.	800	439.47	146.49	62.99	593	439.40	146.47	62.98	403	439.62	146.54	63.01	170	429.85	143.28	61.61	35	215.26	71.75	30.85
Sd.	144	0.43	0.14	0.06	55	0.41	0.14	0.06	143	0.12	0.04	0.02	35	7.78	2.59	1.12	35	106.36	35.45	15.24

	Monday				Tuesday				Wednesday				Thursday				Friday			
	Reward	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km
V1	960	439.15	146.38	62.94	590	439.95	146.65	63.06	300	439.08	146.36	62.93	70	372.20	124.07	53.35	-	-	-	-
V2	760	439.95	146.65	63.06	580	438.47	146.16	62.85	210	437.75	145.92	62.74	40	180.98	60.33	25.94	-	-	-	-
V3	680	439.30	146.43	62.97	450	439.63	146.54	63.01	180	438.50	146.16	62.85	10	140.05	46.68	20.07	-	-	-	-
V4	560	438.47	146.16	62.85	450	439.53	146.51	62.99	130	414.47	138.16	59.41	-	-	-	-	-	-	-	-
Avg.	740	439.22	146.41	62.95	518	439.40	146.47	62.98	205	432.45	144.15	61.98	40	231.08	77.03	33.12	-	-	-	-
Sd.	168	0.609	0.203	0.09	78	0.64	0.21	0.09	71	12.00	4	1.72	30	123.92	41.31	17.76	-	-	-	-

	Monday				Tuesday				Wednesday				Thursday				Friday			
	Reward	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km	Rew.	Time	Km	€/Km
V1	960	439.15	146.38	62.94	490	439.63	146.54	63.01	210	439.65	146.55	63.02	-	-	-	-	-	-	-	-
V2	760	439.95	146.65	63.06	490	438.77	146.26	62.89	160	432.48	144.16	61.98	-	-	-	-	-	-	-	-
V3	680	439.30	146.43	62.97	440	439.10	146.37	62.94	-	-	-	-	-	-	-	-	-	-	-	-
V4	560	438.47	146.16	62.85	360	439.07	146.36	62.93	-	-	-	-	-	-	-	-	-	-	-	-
V5	540	439.43	146.48	62.98	220	439.42	146.47	62.98	-	-	-	-	-	-	-	-	-	-	-	-
Avg.	700	439.26	146.42	62.96	400	439.20	146.4	62.95	185	436.07	145.36	62.50	-	-	-	-	-	-	-	-
Sd.	171	0.54	0.18	0.08	114	0.34	0.11	0.05	25	5.07	1.69	0.73	-	-	-	-	-	-	-	-

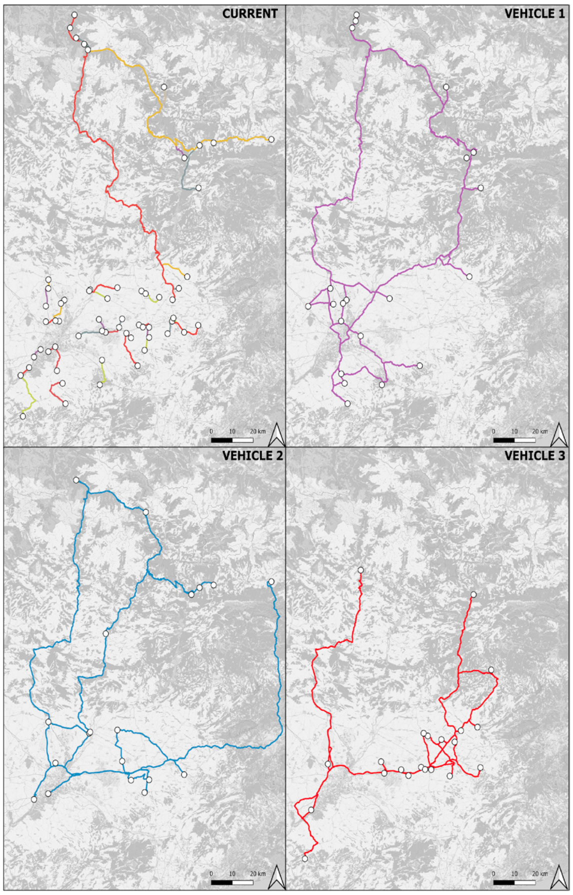

Fig. 3: Comparison between the current route management scenario for health care to municipalities without health care coverage and the application of our model for route planning.

Based on our simulation routes for the current scenario and our proposed model, Table 2 shows the comparative time and costs for both scenarios.

	Total Monday time (min)	Total Monday cost (€)
Scenario 1 (current): Each primary care center that corresponds to each user sends a home health care vehicle	4,320.40	1,394.06
Scenario 2 (model): Application of our model. Hub from *El Pla de San Tirs* with 3 vehicles to manage home routes	1,318.40	188.97
Note: in current scenario both outward and return journeys have been taken into account.		

Table 2: Comparison of route management of the current scenario versus the scenario with the application of our model for the first day of the week (Monday).

The application of our route planning and management model in the municipality of Bausen would allow for an efficient provision of healthcare services to the population that currently lacks it. Moreover, our model would not only provide coverage for this municipality, but also plan health care in other rural municipalities in Catalonia that are in the same situation. In this way, our model offers the possibility to explore different scenarios and to make decisions that contribute to improving health care coverage in depopulated areas of the mountainous region, which is of great importance for public authorities.

7. Conclusions and Future Research

Video consultations have been positioned as a possible alternative to provide healthcare coverage to rural areas where the population does not have the minimum health services available as in large cities (Wesson and Kupperschmidt, 2013). However, the use of technology is a major barrier for the population that mainly resides in these areas, such as the elderly over 60 years of age (Johansson et al., 2014). For this reason, there is a need for new proposals to provide healthcare coverage to these rural areas, especially in the mountains, so as not to leave the population without healthcare coverage. This is how our proposed model for planning home care routes is positioned as a complement to video-consultations and would allow public administrations to have more options for providing minimum health services to all parts of the territory. Our study has led to other future research, such as (1) the study of costs for different rural geographical areas, beyond those analysed in our study, (2) the implementation of our model for emergency cases, in which not only primary care services but also hospital centres would be involved, and (3) evaluating the impact of the proposed route planning model on the wellbeing of the rural population.

Acknowledgements

This work has been partially funded by the Spanish Ministry of Science (PID2019-111100RB-C21-C22/AEI/10.13039/501100011033), as well as by the eHealth Center at the Open University of Catalonia under the framework of the eHealth Research Promotion Programme.

References

Assembly, U.G., 2005. Resolution adopted by the general assembly 60/1. 2005 world summit outcome. Sixtieth Session. Agenda Items 46.

Aldomà i Buixadé, I., Mòdol Ratés, J.R., Morell i Rosell, R., 2022. Atles del món rural 2022: despoblament o revitalització? Associació d'Iniciatives Rurals de Catalunya. https://repositori.udl.cat/items/85dcc169-8107-42e0-8422-bcf96873404a.

Cheng, L., Yang, M., De Vos, J., Witlox, F., 2020. Examining geographical accessibility to multi-tier hospital care services for the elderly: A focus on spatial equity. Journal of Transport & Health 19, 100926.

Clarke, G., Wright, J.W., 1964. Scheduling of vehicles from a central depot to a number of delivery points. Operations Research 12, 568–581.

Elkington, J., 1998. Cannibals with forks: Triple bottom line of 21st century business. Environmental Quality Management 8, 37–51.

Fikar, C., Hirsch, P., 2017. Home health care routing and scheduling: A review. Computers & Operations Research 77, 86–95.

Gerssen-Gondelach, S.J., Faaij, A.P., 2012. Performance of batteries for electric vehicles on short and longer term. Journal of Power Sources 212, 111–129.

Gutiérrez, E.V., Gutiérrez, V., Vidal, C.J., 2013. Home health care logistics management: Framework and research perspectives. International Journal of Industrial Engineering and Management 4, 173.

Johansson, A.M., Lindberg, I., Söderberg, S., 2014. Patients' experiences with specialist care via video consultation in primary healthcare in rural areas. International Journal of Telemedicine and Applications 2014, 9–9.

Landers, S., Madigan, E., Leff, B., Rosati, R.J., McCann, B.A., Hornbake, R., MacMillan, R., Jones, K., Bowles, K., Dowding, D., Lee, T., Moorhead, T., Rodriguez, S., Breese, E., 2016. The future of home health care: a strategic framework for optimizing value. Home Health Care Management & Practice 28, 262–278.

Martins, L.d.C., Tordecilla, R.D., Castaneda, J., Juan, A.A., Faulin, J., 2021. Electric vehicle routing, arc routing, and team orienteering problems in sustainable transportation. Energies 14, 5131.

Nelson, J.A., Stover Gingerich, B., 2010. Rural health: Access to care and services. Home Health Care Management & Practice 22, 339–343.

Norman, S., 2006. The use of telemedicine in psychiatry. Journal of Psychiatric and Mental Health Nursing 13, 771–777.

Panadero, J., Ammouriova, M., Juan, A.A., Agustin, A., Nogal, M., Serrat, C., 2021. Combining parallel computing and biased randomization for solving the team orienteering problem in real-time. Applied Sciences 11, 12092.

Pinilla, V., Sáez, L.A., 2017. Rural depopulation in spain: genesis of a problem and innovative policies. Centre for Studies on Depopulation and Development of Rural Areas , 1–23.

Qidwai, W., Beasley, J.W., Gomez-Clavelina, F.J., 2008. The present status and future role of family doctors: a perspective from the international federation of primary care research networks. Primary Health Care Research & Development 9, 172–182.

Salas, V., López, J., 2002. Economía y política de la financiación de servicios públicos en territorios con desigual densidad de demanda. Revista de Economía Aplicada 10, 121–150.

Singh, G.K., Siahpush, M., 2014. Widening rural–urban disparities in life expectancy, US, 1969–2009. American Journal of Preventive Medicine 46, e19–e29.

Toledo, F.G., Triola, A., Ruppert, K., Siminerio, L.M., 2012. Telemedicine consultations: an alternative model to increase access to diabetes specialist care in underserved rural communities. JMIR Research Protocols 1, e2235.

Wesson, J.B., Kupperschmidt, B., 2013. Rural trauma telemedicine. Journal of Trauma Nursing 20, 199–202.