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# Sustainability criteria for transport of home care staff and frail people

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**Abstract** *Transport is a major driver of climate change and other negative effects. At the same time demographic change increases the need for home care services and transport of frail people. This short paper gives an overview of today's means of transport for home care staff and frail people, and maps out the development of sustainability criteria to optimize these transports.*

## 1. Introduction

The transport sector was responsible for 14 % of global greenhouse gas (GHG) emissions in 2010 [1], in addition there are several other external effects such as noise and local air pollution. Another phenomenon in industrialized countries is the shift in demographics, leading to an increase of the older population. Within the next four decades the population aged 65 and over is expected to double; life expectancy at the age of 65 is 20.9 years for women and 17.6 years for men on average, while disability free life expectancy is 9.5 and 9.4 years respectively [2]. In addition, more and more people suffer from diseases such as obesity [3] or dementia [2].

These factors lead to a rise in the number of care dependent people. Consequently, a future rise in elderly care services can be expected, therefore leading to more mobility of home care (HC) staff [4]. A number of people in need of HC as well as other parts of the population have to cope with limited mobility. Today their mobility needs are usually met through a number of different transport services. Hence, there is an increase in traffic from HC services as well as transport services for frail people. Today these types of mobility are considered in literature and there are ways to optimize the transport of HC staff [4-9] as well as transport services [10,11]. However, approaches to solve these problems of transport are mainly trying to maximize economic efficiency by minimizing either cost or the length of travel time, hardly taking into account social or ecological criteria.

As [12] as well as [13] show, although economic and ecological objectives are sometimes congruent, they are not equal. Social criteria are mostly limited to service quality for the transport of frail people [14,15] and are included to a limited

extent for the transport of HC staff. [8] include few social criteria for HC staff such as reduction of overtime, preferences regarding clients and working hours as well as minimizing of activities the nurse is overqualified for.

This obviously lacks the inclusion of ecological and social criteria and therefore does not take into account all three pillars of sustainability (economy, ecology, social). The aim of this study is the development of sustainability criteria for transport of frail people and HC staff. This enables future research to concentrate not only on economic but also on ecological and social aspects of transport problems in this area. To the best of our knowledge a comprehensive catalogue of sustainability criteria in this problem area is missing. Hence, our main contributions are to give a structured overview of possible means of transport and to provide sustainability criteria based on our research in this field [4,7,8,9,12,16,17,18]. Moreover, we present numerical studies based on [17] that show how the valuation of single sustainability criteria may change depending on the service policy of a transport provider for frail people.

## 2. Problem description

HC staff is one factor that increases traffic due to demographic change. It has to visit clients at their homes to perform different services. The qualification level of the staff needs to be considered, e.g. nurses caring for wounds need a different qualification than staff cleaning the house. Besides, other assignment constraints need to be considered, these include e.g. preferences regarding gender of staff or pet allergies. In addition to sending the right worker to the right client, time windows need to be considered as clients need some medical treatments at a certain time. Maximum working times of staff as well as break times need to be included in the optimization. At the moment several means of transport are used by HC staff, mainly depending on the geographic location, but also on the type of service provided. In addition, there are means of transport proposed in literature, which are not in practice yet. To optimize the scheduling of HC services using a single mobility concept, different problem definitions from literature have to be extended, namely the Dial a Ride Problem (DARP) [11] and the Vehicle Routing Problem (VRP) [8]. These extensions are problem specific as well as dependent on the mobility concept. In general, all mobility concepts may be subject to time-dependency and static or dynamic information. Some mobility concepts require synchronization between HC staff and/or their means of transport. In Table 1 we present an overview of mobility concepts in HC and their related logistical problem definitions. To the best of our knowledge, there exist no solution methods in literature for some of the concepts applied to HC. If concepts can be optimized with already published methods this is denoted with references in Table 1.

| Mobility Concept \ Logistical Problem | | DARP | VRP | Synchronization |
|---|---|---|---|---|
| **car** | | | | |
| | individual use [4,5,6,8] | | X | |
| | car sharing | | X | X |
| | trip sharing [7] | X | | X |
| **(e-)bike** | | | X | |
| | individual use [4,5,6,8] | | X | |
| | (e-)bike sharing | | X | X |
| **walking** | [4,5,6,8] | | X | |
| **taxis** | [19] | | X | |
| **bus service** | [7] | X | | X |
| **public transport** | | | | |
| | without combination [9] | | X | |
| | with shared (e-)bikes or cars | | X | X |
| | with own (e-)bikes or scooters [9] | | X | |

Table 1: Mobility concepts in HC and their underlying logistical problems

In Table 2 we present an overview of mobility concepts for transport services for frail people and their related logistical problem definitions. In addition to the DARP, the Shortest Path Problem (SPP) [9] and the Stacker Crane Problem (SCP) [17] can be used as basic problem definitions. As mentioned before for HC, they need to be extended by problem specific constraints. The extensions related to the mobility concepts are the same as for HC. If mobility concepts for the transport of frail people can be optimized with already published methods this is denoted with references in Table 2.

| Mobility Concept \ Logistical Problem | | SPP | DARP | SCP | Synchronization |
|---|---|---|---|---|---|
| **special buses** | | | | | |
| | without combination [10,11] | | X | | |
| | with transfers | | X | | X |
| | in combination with taxis [11] | | X | | X |
| **taxis** | | | | | |
| | if rides are shared [11] | | X | | |
| | if only one patient is transported at a time | | | X | |
| **ambulances** | | | | | |
| | if rides are shared [10,11,17] | | X | | |
| | if only one patient is transported at a time [17] | | | X | |
| **public transport** | | | | | |
| | if an assistant picks up more than one customer and departure and/or arrival point are not equal | | X | | |
| | if only one patient is accompanied at a time [9] | | | X | |
| | if only one patient is accompanied between two locations | X | | | |
| **private car** | | X | | | |

Table 2: Mobility concepts for the transport of frail people and their underlying logistical problems

The presented means of transport differ in their economic, ecological and social impacts. Thus, it is necessary to define a catalogue of sustainability criteria for transport of HC staff and frail people.

## 3. Method

The sustainability criteria are identified in a first stage through desk research. A mix of scientific journals and university publications, such as dissertations, found in scientific databases (e.g., Scopus, Google Scholar, Web of Science), as well as

grey literature (e.g., reports, websites or leaflets from cities and organizations) and textbooks are used. Existing criteria in related fields such as those for home services in general [20] or the service quality criteria for transport services [15] are evaluated. The second stage is the conduction of qualitative expert interviews with several managers at different hierarchy levels in HC organizations. This stage consists of the following steps: choosing experts – formulate an interview guideline – perform the interviews – transcription of the interviews – content analysis. The interviews are made in three Austrian provinces that include urban as well as rural areas. The interviews are conducted as multi-person interviews with two to four interview partners to increase creativity [21]. These interviews are the key to identify social criteria. The interviews are transcribed and coded for different aspects and criteria. The outcomes build the foundation for the catalogue of sustainability criteria. For the case of transport of frail people, we perform numerical studies with real-world data based on the algorithms presented in [17] to show the trade-off between ecological, social and economic goals with real-world data.

## 4. Preliminary results

Up to now we have finished the desk research and performed the interviews. Currently, the interviews are transcribed, which will be followed by the content analysis. The final results of our study will be presented at the conference. Preliminary results indicate that research and practice are still apart, as many real-world problems are not dealt with yet in research. The extent to which different aims of one pillar of sustainability are achieved determines the achievement of the others. In addition, some means of transport are more environment-friendly than others, also depending on the geographic area [18]. Table 3 presents an outlook on few examples of criteria identified and adapted from literature [15,22] and the performed interviews. Note that single criteria can be relevant in different pillars.

| **Ecological** | **Social** | **Economic** |
|---|---|---|
| Population exposed to noise >55 dB | Social Contacts | Number of staff needed |
| Land consumption for transport infrastructure (e.g. parking) | Staff / client participation in decision making | Costs for clients, providers and the local government |
| GHG emissions from transport per costumer | Weather-sensitive scheduling | Number of vehicles in operation |
| Emissions of local air pollutants per customer | Total time spent in traffic | Total time spent in traffic |

Table 3: Outlook on a few examples of criteria for the three pillars of sustainability

The numerical studies with real-world data based on [17] show that depending on the service quality a patient transport service provider offers – ranging in five steps from “excellent” (1) to “standard” (3) and “bad” (5) – the achievement of the goals

of the single pillars of sustainability differs. A service quality of 3 is currently standard for service providers. If the service quality worsens, the utilization of the ambulances increases. The impact of different service qualities on the single pillars of sustainability is shown below:

- Ecological: A service quality of 5 is favourable to reach the goals of this pillar. Compared to 1 (3), the number of deployed ambulances can be reduced by about 14 % (5 %). In case of the drive times a reduction of about 15 % (9 %) is achieved. This leads to less negative externalities of transport.
- Social: A service quality of 1 is favourable to reach the goals of this pillar. The patients have on average shorter waiting times, are transported together with less other people and enjoy a more individual service. The staff is confronted with a higher total workload but it has to take care of less patients at a time. It can be assumed that patients as well as staff are more satisfied.
- Economic: A service quality of 5 is favourable to reach the goals of this pillar. Compared to 1 (3), the total operational cost can be decreased by about 13 % (6 %). Under ceteris paribus assumptions, it can be presumed that the profit of the service provider increases.

## 5. Conclusions

This short paper presents a structured overview of possible means of transport for HC staff and frail people. These have different impacts for providers, staff and clients with respect to ecological, social and economic objectives. The study aims at providing sustainability criteria for transport in this problem area. Since this research is still in progress, we present preliminary results in this paper. Our final results will be presented at the conference. Additionally, we present numerical studies that show how the valuation of single sustainability criteria in the transport of frail people changes depending on the service policy of the provider. The results show big trade-offs between the single pillars of sustainability. Future research will be focused on the operationalization of sustainability criteria and the way they can be implemented in algorithms that optimize the scheduling of these services.

## References

1. IPCC CLIMATE CHANGE 2014 SYNTHESIS REPORT Longer report. IPCC Fifth Assessment Synthesis Report. IPCC (2014)
2. OECD Health at a Glance 2013: OECD Indicators. OECD Publishing. doi:10.1787/health_glance-2013-en (2013)
3. European Commission Sustainable development in the European Union - 2013 monitoring report of the EU sustainable development strategy. eurostat Statistical books. European Commission, Luxembourg. doi:10.2785/11549 (2013)

4. Rest, K.-D., Trautsamwieser, A. and Hirsch, P. Trends and risks in home health care. Journal of Humanitarian Logistics and Supply Chain Management. Vol 2:1, pp. 34-53 (2012)
5. Cheng, E and Rich, J.L. A home health care routing and scheduling problem. Technical report (1998)
6. Eveborn, P, Flisberg, P. and Rönnqvist, M. LAPS CARE—an operational system for staff planning of home care. European Journal of Operational Research. Vol 171:3, pp. 962-976 (2006)
7. Fikar, C. and Hirsch, P. A matheuristic for routing real-world home service transport systems facilitating walking. In press: Journal of Cleaner Production. http://dx.doi.org/10.1016/j.jclepro.2014.07.013 (2014)
8. Trautsamwieser, A. and Hirsch, P. Optimization of daily scheduling for home health care services. Journal of Applied Operational Research. Vol 3:3, pp. 124-136 (2011)
9. Rest, K.-D. and Hirsch, P. Time-dependent travel times and multi-modal transport for daily home health care planning. Paper presented at the TRISTAN VIII - The Eight Triennial Symposium on Transportation Analysis, JUN 09-14, 2013, San Pedro de Atacama, Chile (2013)
10. Schilde, M. Solution methods for the dynamic stochastic dial-a-ride problem with time-dependent travel speeds. PhD thesis University of Vienna (2011)
11. Cordeau, J.-F. and Laporte, G. The dial-a-ride problem: models and algorithms. Annals of Operations Research. Vol 153:1, pp. 29-46. (2007)
12. Oberscheider, M., Zazgornik, J., Henriksen, C.B., Gronalt, M. and Hirsch, P. Minimizing driving times and greenhouse gas emissions in timber transport with a near-exact solution approach. Scandinavian Journal of Forest Research. Vol 28:5, pp. 493-506 (2013)
13. Bektaş, T. and Laporte, G. The pollution-routing problem. Transportation Research Part B: Methodological. Vol 45:8, pp.1232-1250 (2011)
14. Paquette, J., Cordeau, J.-F. and Laporte, G. Comparative study of various models for the transport demand problem. INFOR. Vol 45:2, pp. 95-110 (2007)
15. Paquette, J., Bellavance, F., Cordeau, J.F. and Laporte, G. Measuring quality of service in dial-a-ride operations: The case of a Canadian city. Transportation. Vol 39:3, pp. 539-564 (2012)
16. Fikar, C. and Hirsch, P. Planning of Home Health Care Transport Services with Subroutes and Interdependencies. In: Second Annual Conference of the EURO Working Group on Vehicle Routing and Logistics Optimization, JUL 7-10, 2013, Southampton, United Kingdom (2013)
17. Oberscheider, M. and Hirsch, P. Analysis of different Levels of Service for a static Multi Depot dial-a-ride Problem (Working Paper). Institute of Production and Logistics, University of Natural Resources and Life Sciences, Vienna (2014)
18. Fikar, C. and Hirsch, P. Evaluation of trip sharing concept for home health care services (Working paper). Institute of Production and Logistics, University of Natural Resources and Life Science (2014)
19. Quintanilla, S., Ballestin, F., Lino, M.P., Pérez, M.A. and Valls, V. Minimizing the cost in the daily routes of the Hospital at Home. http://www.euro-online.org/conf/euro26/treat_abstract?paperid=13390 (accessed 11/11/2014).

20. Halme, M., Anttonen, M., Hrauda, G. and Kortman, J. Sustainability evaluation of European household services. Journal of Cleaner Production. Vol 14:17, pp. 1529-1540 (2006)
21. Froschauer, U. and Lueger, M. Das qualitative Interview: Zur Praxis interpretativer Analyse sozialer Systeme. Vol 2418. UTB (2003)
22. Haghshenas, H. and Vaziri, M. Urban sustainable transportation indicators for global comparison. Ecological Indicators. Vol 15:1, pp. 115-121 (2012)