Mapping Opportunities for Enhancing Effectiveness of Health Care System by GIS Based Accessibility Analyses

Locating Core and Support Services within Long Distances in Northern Finland

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Ossi Kotavaara (PhD), Tommi Hakkarainen (MSc), Tiina Huotari (MSc), Timo Keistinen* (Ministerial Counsellor) & Jarmo Rusanen (Prof)

Department of Geography, University of Oulu, Finland
*Ministry of Social Affairs and Health, Finland

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STUDY HAS A CONNECTION WITH

Transport geography
Geographic information systems (GIS)
Accessibility analysis
Cartography
Logistics
Operations research

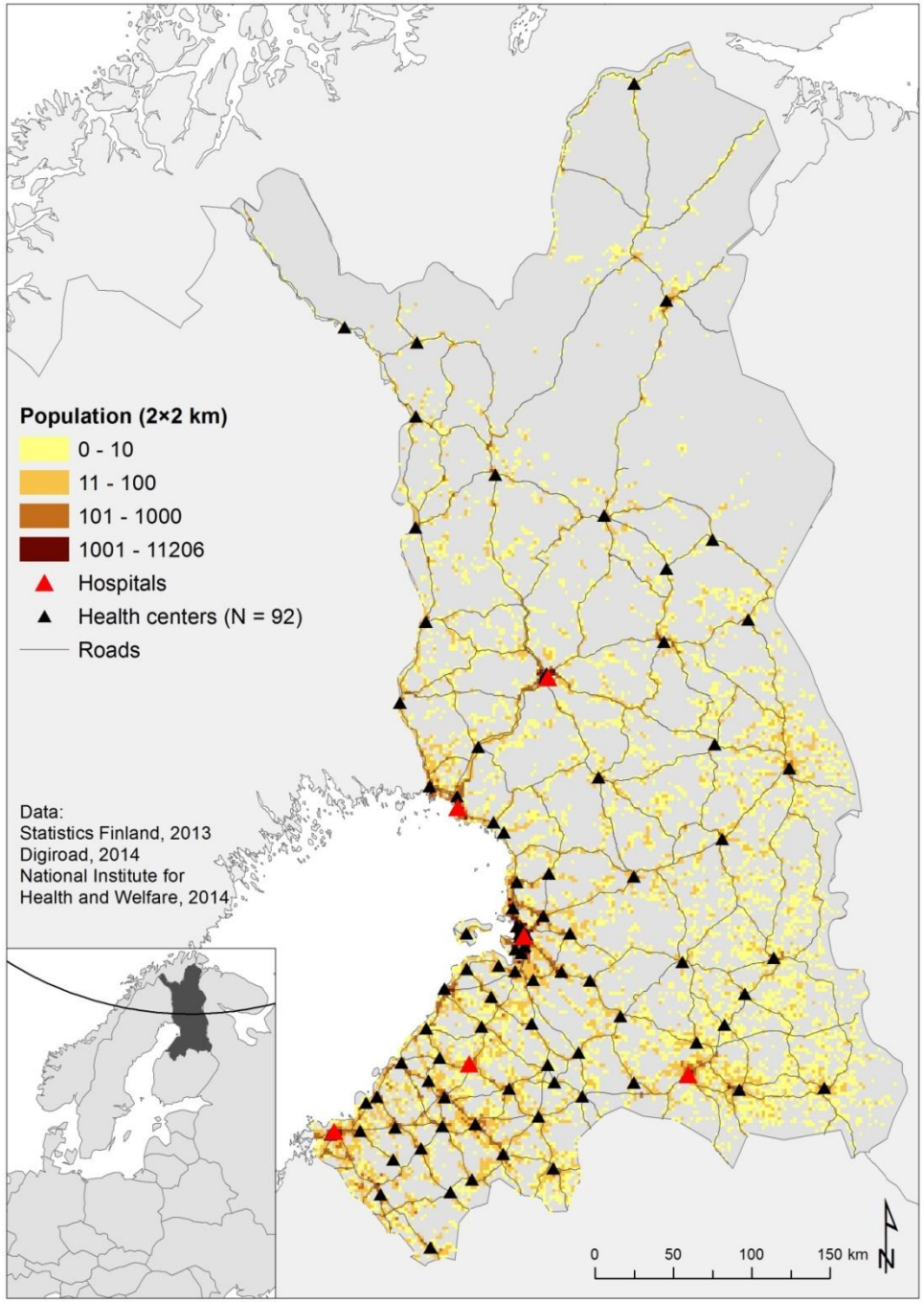
MEASURING ACCESSIBILITY

"Accessibility... ...is the extent to which the land-use transport system enables (groups of) individuals or goods to reach activities or destinations by means of a (combination of) transport mode(s)."
Geurs & Ritseman van Eck (2001: 19)

HEALTH CARE WITHIN LONG DISTANCES AND LOW DEMAND

- There is pressure to reorganize Finnish healthcare services.
- Upper level coordination.
- Peripheral areas having decreasing and aging populations are challenging for effective health care.

- Healthy support services -project
  - *Effective, user-centered and scalable support service models in long distance health care systems*
  - WP 4: *Accessibility, long distance and location-allocation*
  - Partners: Oulu Business School and Industrial Engineering and Management, University of Oulu
  - Main funding: TEKES, Finnish Funding Agency for Innovation



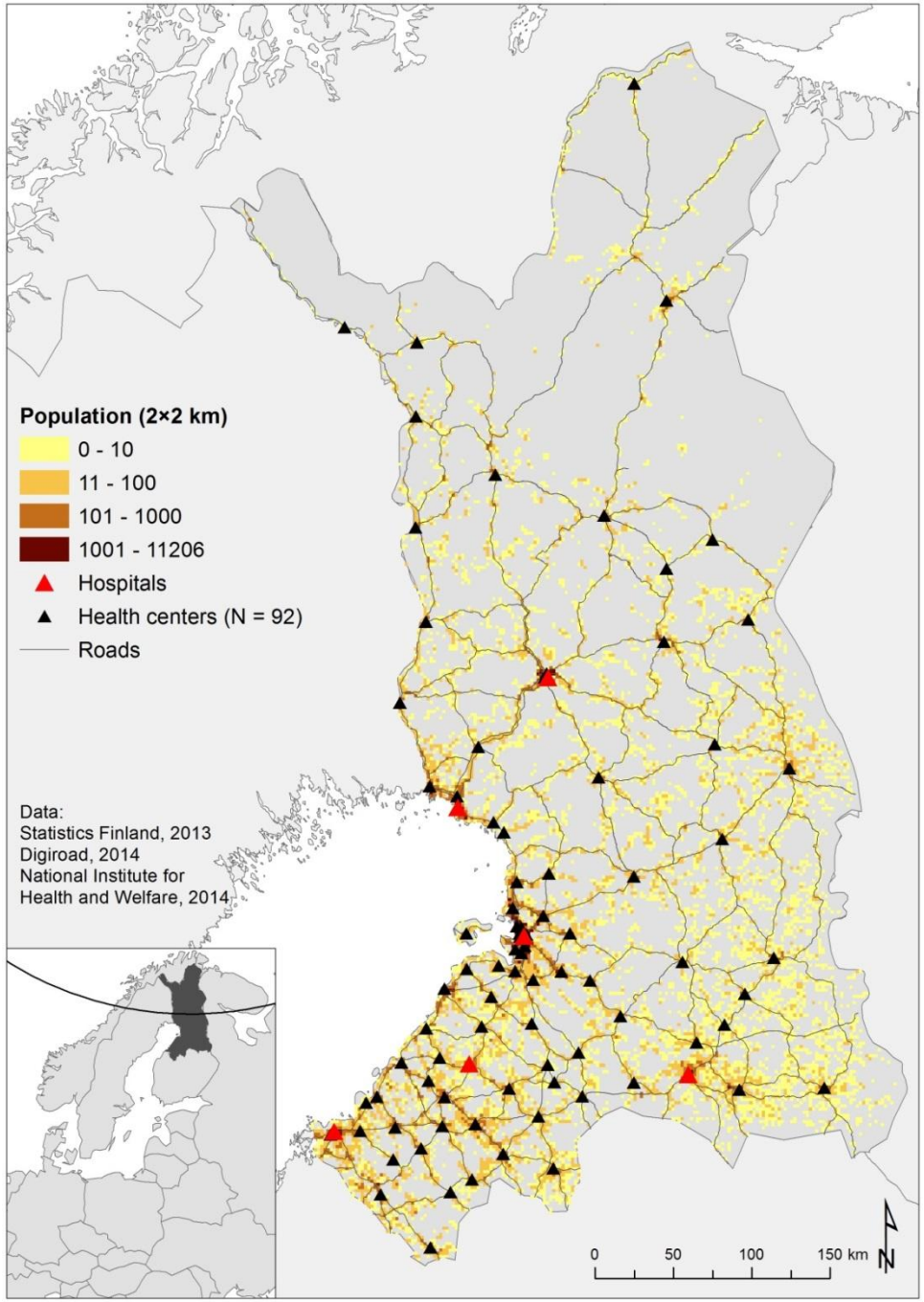
HEALTH CARE WITHIN LONG DISTANCES AND LOW DEMAND

Aim is to find ways to develop the health care system more efficient by two accessibility based approaches

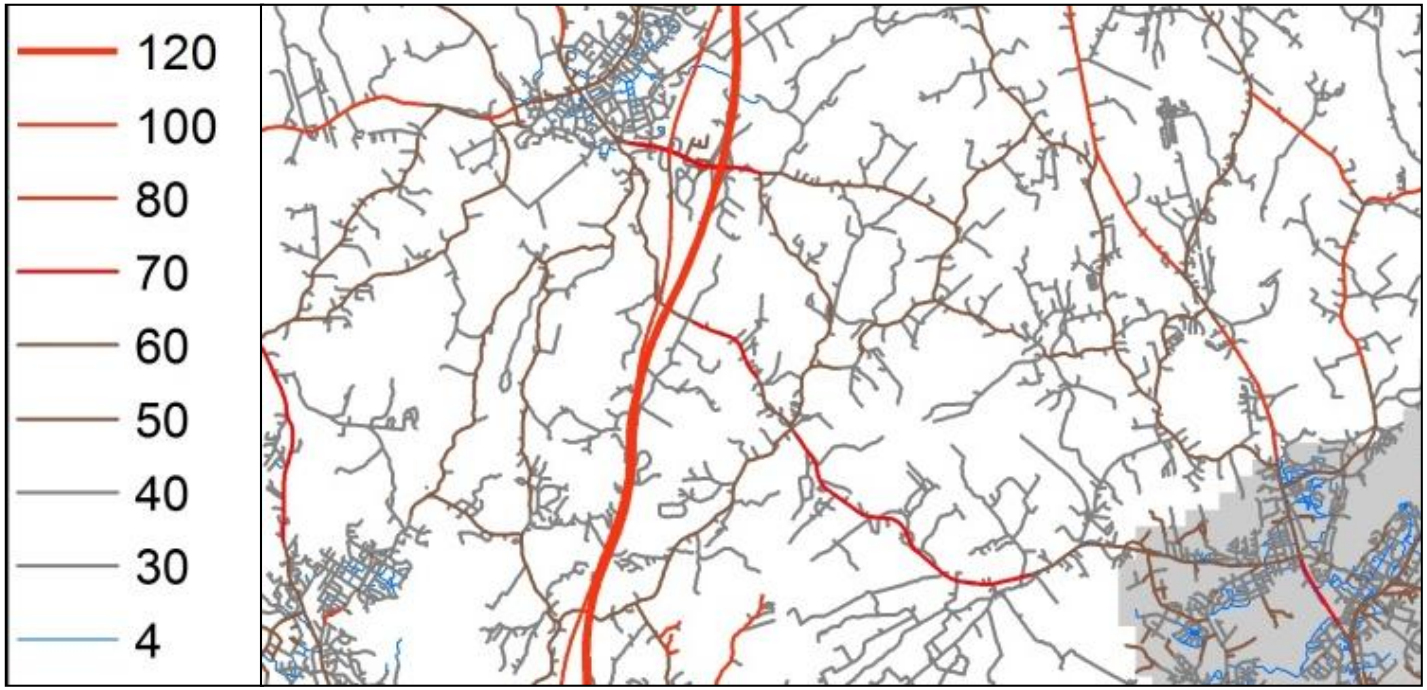
1. Reduce the number of health centers **in less harmful order** by using location-allocation methods
2. Considering (spatial aspects of) **opportunities for centralized warehousing functions by comparing effectiveness of potential sites** by delivery route scenarios.

Data for GIS based analysis

- Population grid cell data
  - Statistics Finland
- Health care facilities: hospitals and health centers
  - THL, geocoding
- Road network data
  - Finnish road administration



EXAMPLE OF NETWORK DATA INCLUDING TRAVEL SPEED ESTIMATES (KM/H)



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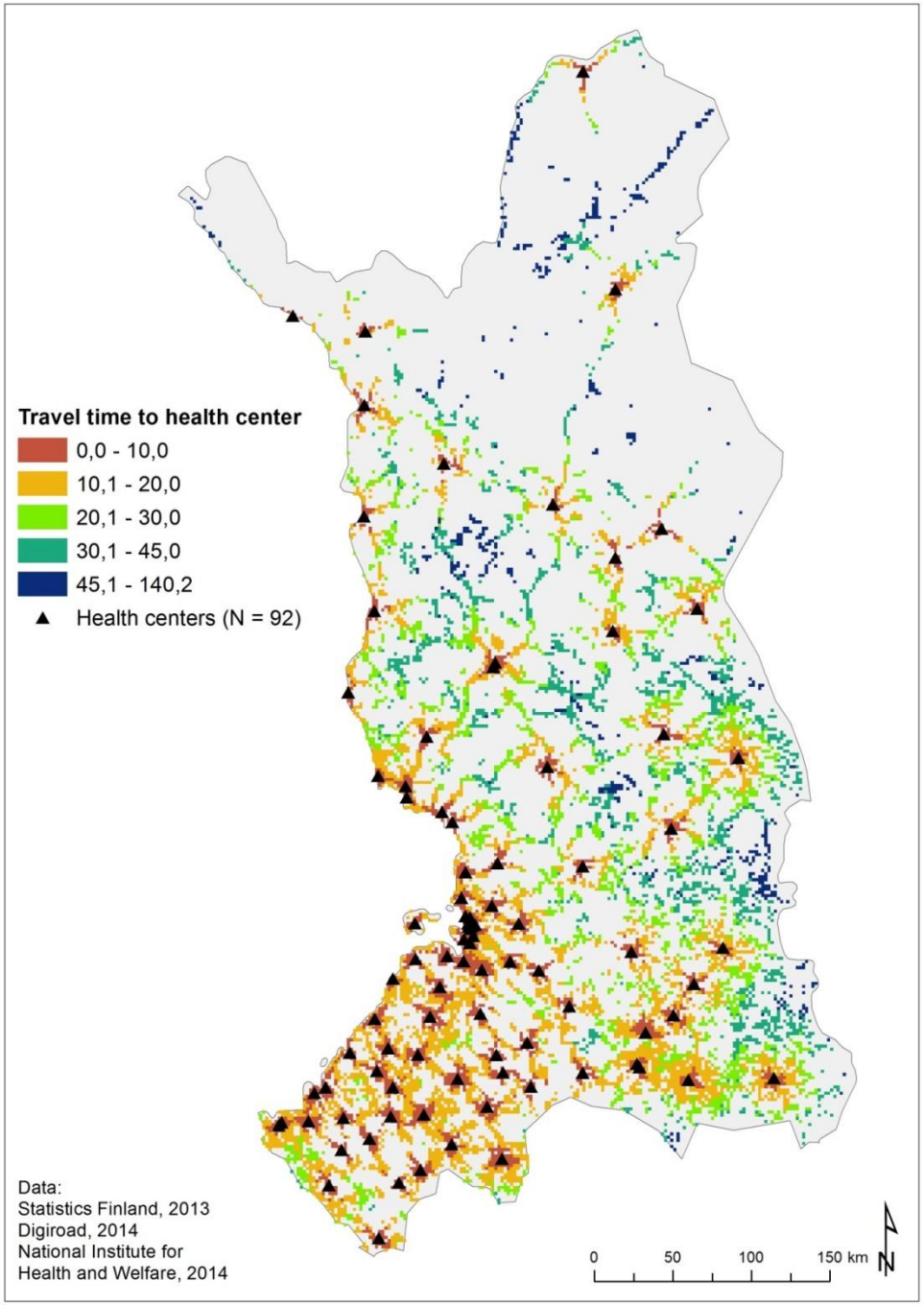
ACCESSIBILITY TO BASIC HEALTH CARE

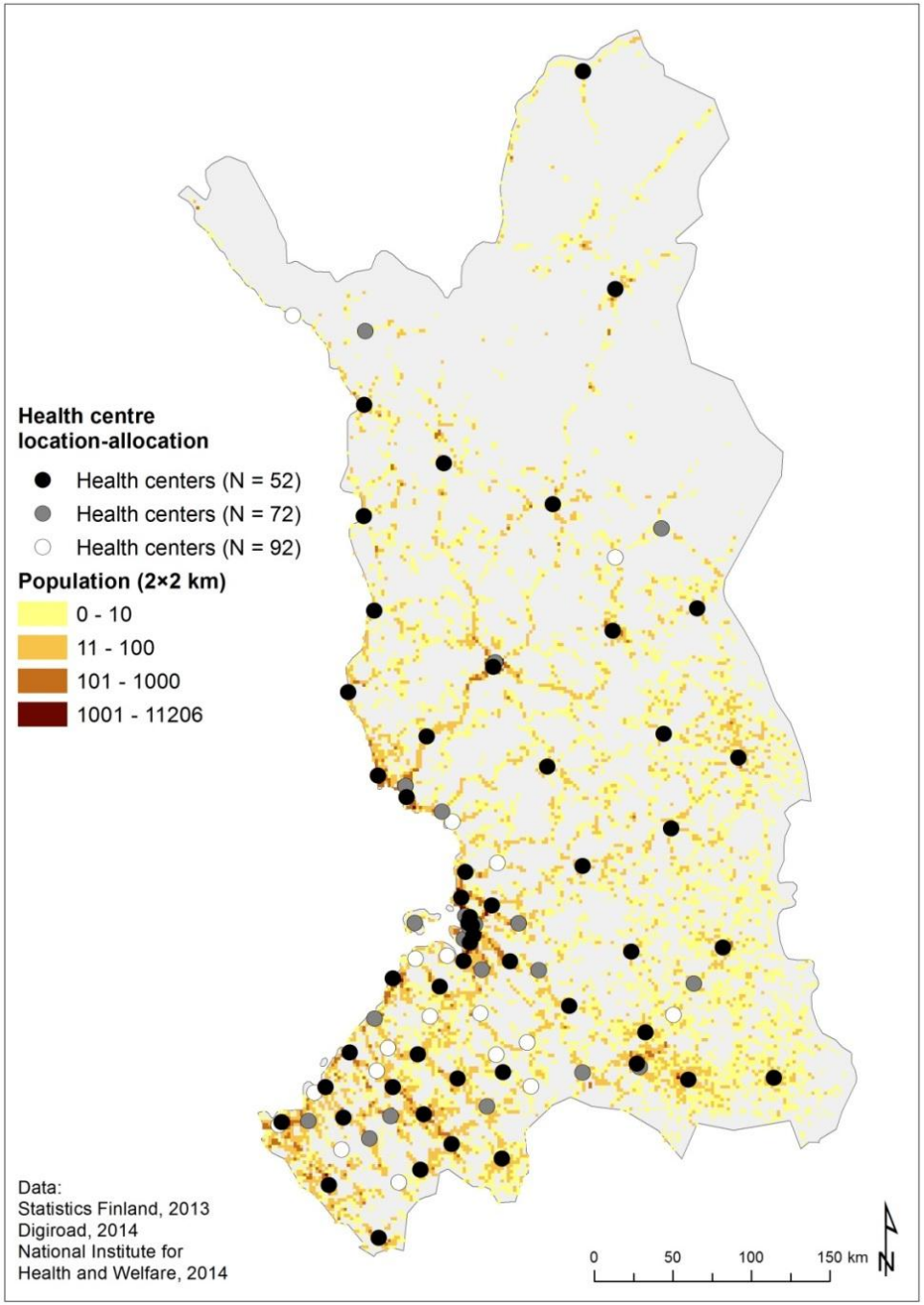
Travel time threshold (minutes)	Share of population (%)				
	52	62	72	82	**92**
10	69.5	73.4	75.9	77.4	**78.4**
20	89.2	91.4	92.8	94.0	**94.4**
30	96.3	97.1	97.5	99.7	**99.7**
45	98.9	99.4	99.4	99.5	**99.5**
60	99.6	99.8	99.8	99.8	**99.8**
90	99.9	99.9	99.9	99.9	**100**



LOCATION-ALLOCATION OF FACILITIES BY ACCESSIBILITY

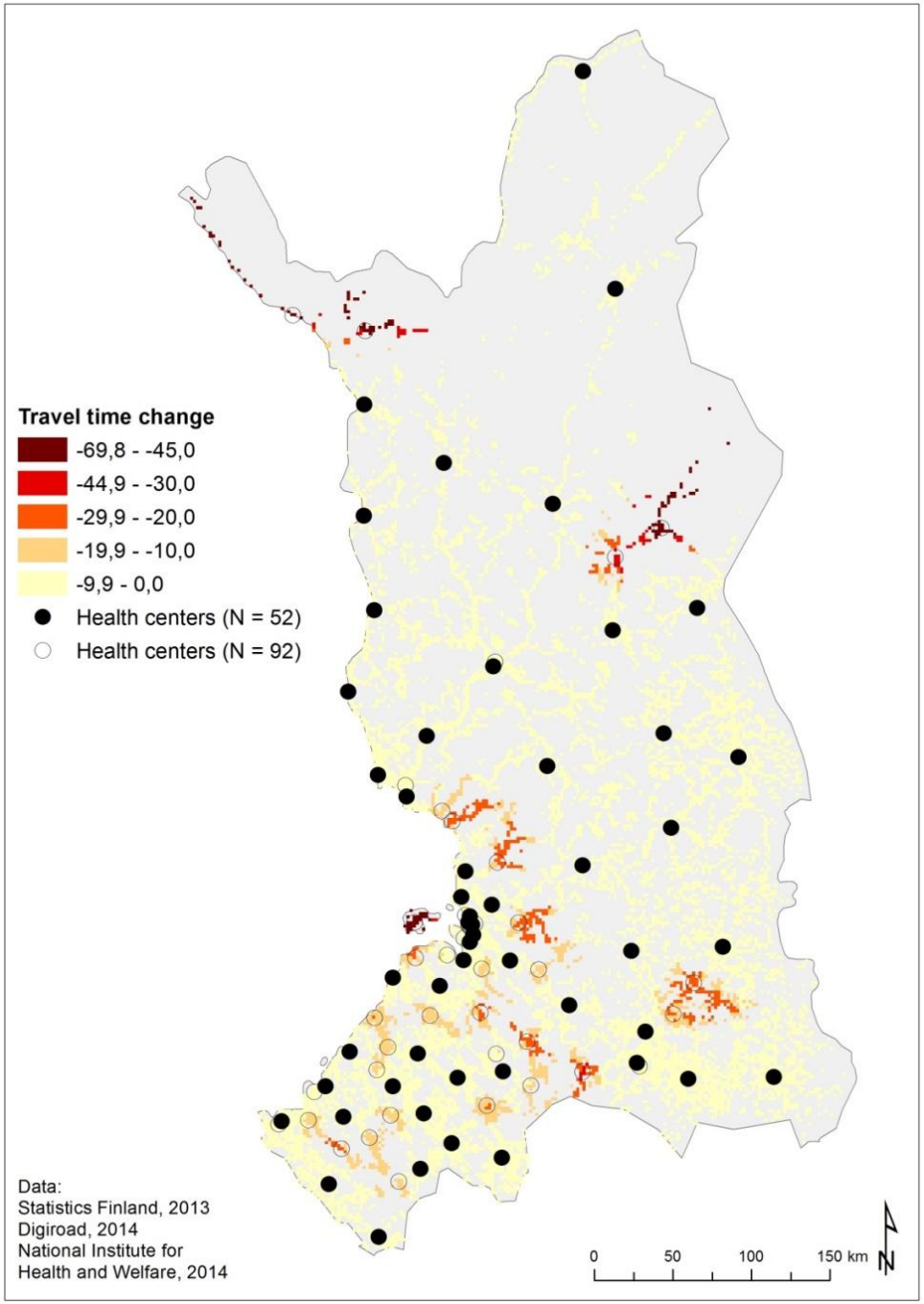
Travel time threshold (minutes)	Share of population (%)				
	52	**62**	**72**	**82**	**92**
10	69.5	73.4	75.9	77.4	78.4
20	**89.2**	**91.4**	**92.8**	**94.0**	**94.4**
30	96.3	97.1	97.5	99.7	99.7
45	98.9	99.4	99.4	99.5	99.5
60	99.6	99.8	99.8	99.8	99.8
90	99.9	99.9	99.9	99.9	100

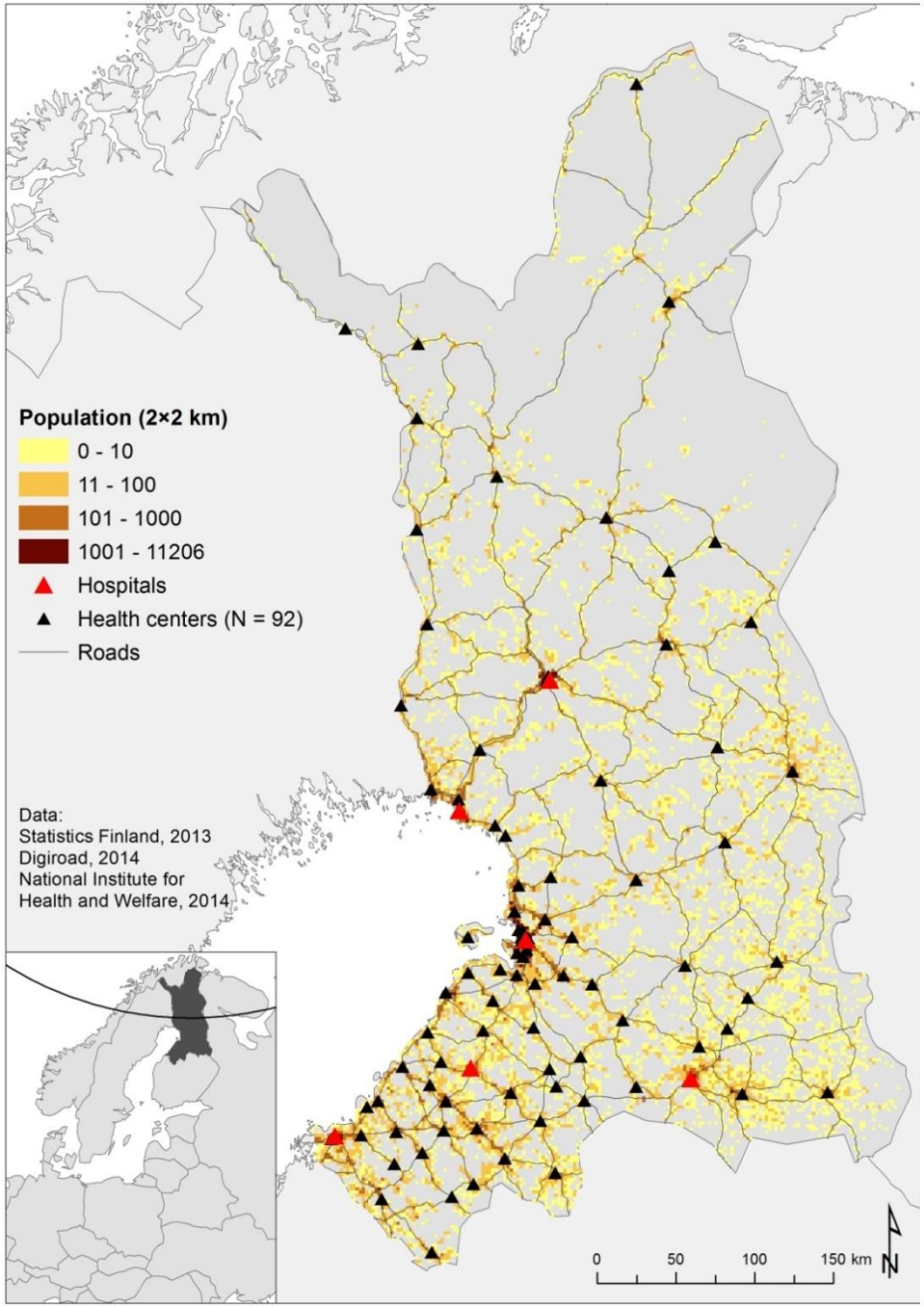
(P-median i.e. minimize impedance approach is used. The analysis maximizes the average accessibility of population, as the travel time sum of population to health centers is minimized.)

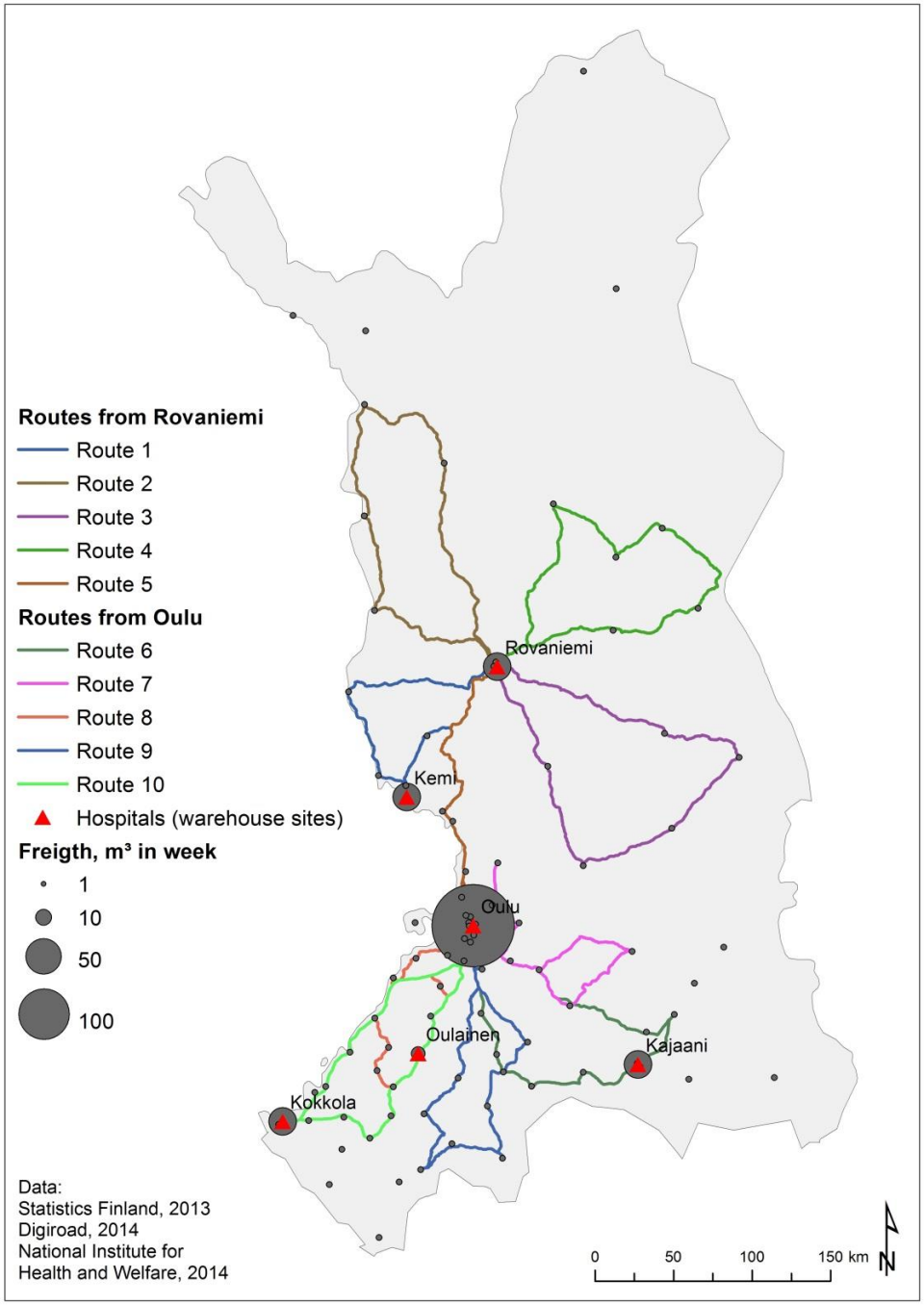


EFFECT TO TRAVEL TIME

Travel time threshold (minutes)	Share of population (%)				
	52	62	72	82	92
10	69.5	73.4	75.9	77.4	78.4
20	89.2	91.4	92.8	94.0	94.4
30	**96.3**	97.1	97.5	99.7	99.7
45	**98.9**	99.4	99.4	99.5	99.5
60	**99.6**	99.8	99.8	99.8	99.8
90	**99.9**	99.9	99.9	99.9	100




Population (2×2 km)
0 - 10
11 - 100
101 - 1000
1001 - 11206
Hospitals
Health centers (N = 92)
Roads
Data:
Statistics Finland, 2013
Digiroad, 2014
National Institute for
Health and Welfare, 2014
0
50
100
150 km
N


Routes from Rovaniemi
Route 1
Route 2
Route 3
Route 4
Route 5
Routes from Oulu
Route 6
Route 7
Route 8
Route 9
Route 10
Hospitals (warehouse sites)
Freigth, m³ in week
1
10
50
100
Rovaniemi
Kemi
Oulu
Oulainen
Kajaani
Kokkola
Data:
Statistics Finland, 2013
Digiroad, 2014
National Institute for
Health and Welfare, 2014
0
50
100
150 km
N

OPTIMIZING LOCATION(S) FOR WAREHOUSE(S) BY DELIVERY ROUTE SCENARIOS FOR ONE OR MORE SITES

- Establishing GIS based delivery route scenarios for all potential combinations in locating one or more warehouses
- Number of combinations for locating warehouses is $X = 2^{sites} - 1$
- Maximum number of routes is defined
- Routes are based on sub-optimal heuristic solution (a tabu search metaheuristics)

N of sites / Number of potential combinations

- 2 / 3
- 3 / 7
- 4 / 15
- 5 / 31
- **6 / 63**
- 10 / 1 023
- 15 / 32 767
- 20 / 1 048 575

Sites = 2

AB
01
10
11

Sites = 3

ABC
001
010
011
100
101
110
111

Sites = 5

ABCDE
00001
00010
00011
00100
00101
00110
00111
01000
01001
01010
01011
01100
01101
01110
01111
10000
10001
10010
10011
10100
10101
10110
10111
11000
11001
11010
11011
11100
11101
11110
11111

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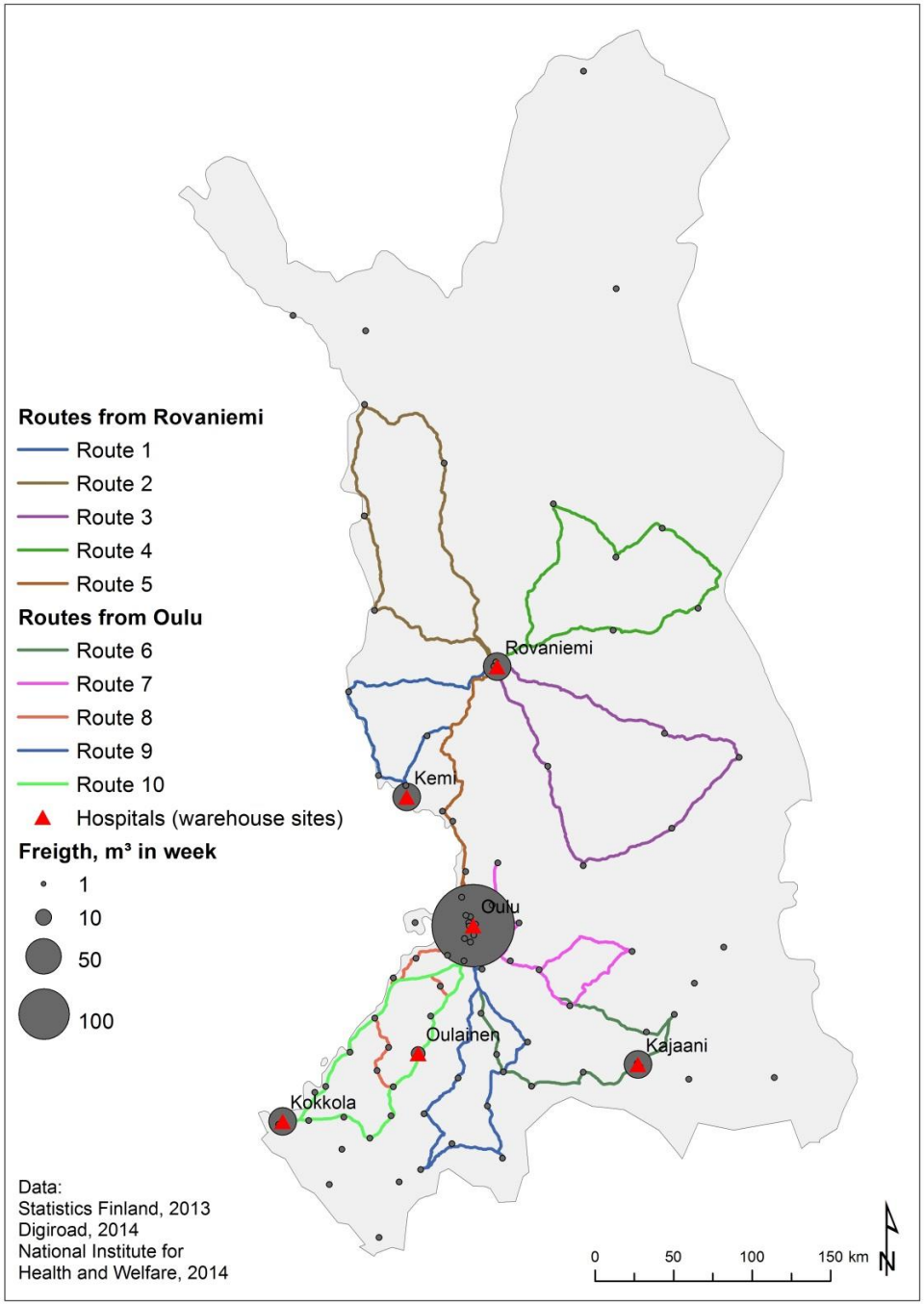
ENHANCED ANALYSIS WITH WEIGHTED ROUTING INCLUDING EFFICIENCY TESTING AND GREEDY HEURISTICS

Parameters for computation:

- Maximum number of delivery routes for each warehouse – 5 routes.
- Maximum travel time of each route – 9 h.
- Start and stops - 10 min.
- Optimizing efficiency of each route
  - Minimum efficiency - max travel time for 1 m³ is 120 min.
  - heuristic improvements – faster computation.
- Minimum coverage threshold of route setting – 90 % of highest potential volume m³.



DELIVERY ROUTE SCENARIOS: TWO WAREHOUSES AND SIX POTENTIAL SITES

Reached health centres (of 92)	Travel time (h)	Sites					
		Kokkola	Rovaniemi	Kemi	Oulainen	Kajaani	Oulu
91	**92,4**	**0**	**1**	**0**	**0**	**0**	**1**
91	92,9	0	1	0	1	0	0
91	104,7	0	1	0	0	1	0
90	114,0	1	1	0	0	0	0
88	86,1	0	0	1	1	0	0
88	91,4	0	0	1	0	0	1
88	100,7	0	0	1	0	1	0
87	98,3	1	0	1	0	0	0
87	129,2	0	1	1	0	0	0
83	78,8	1	0	0	0	0	1
83	81,2	0	0	0	1	0	1
83	82,7	0	0	0	0	1	1
79	73,9	0	0	0	1	1	0
79	83,3	1	0	0	1	0	0
78	84,4	1	0	0	0	1	0

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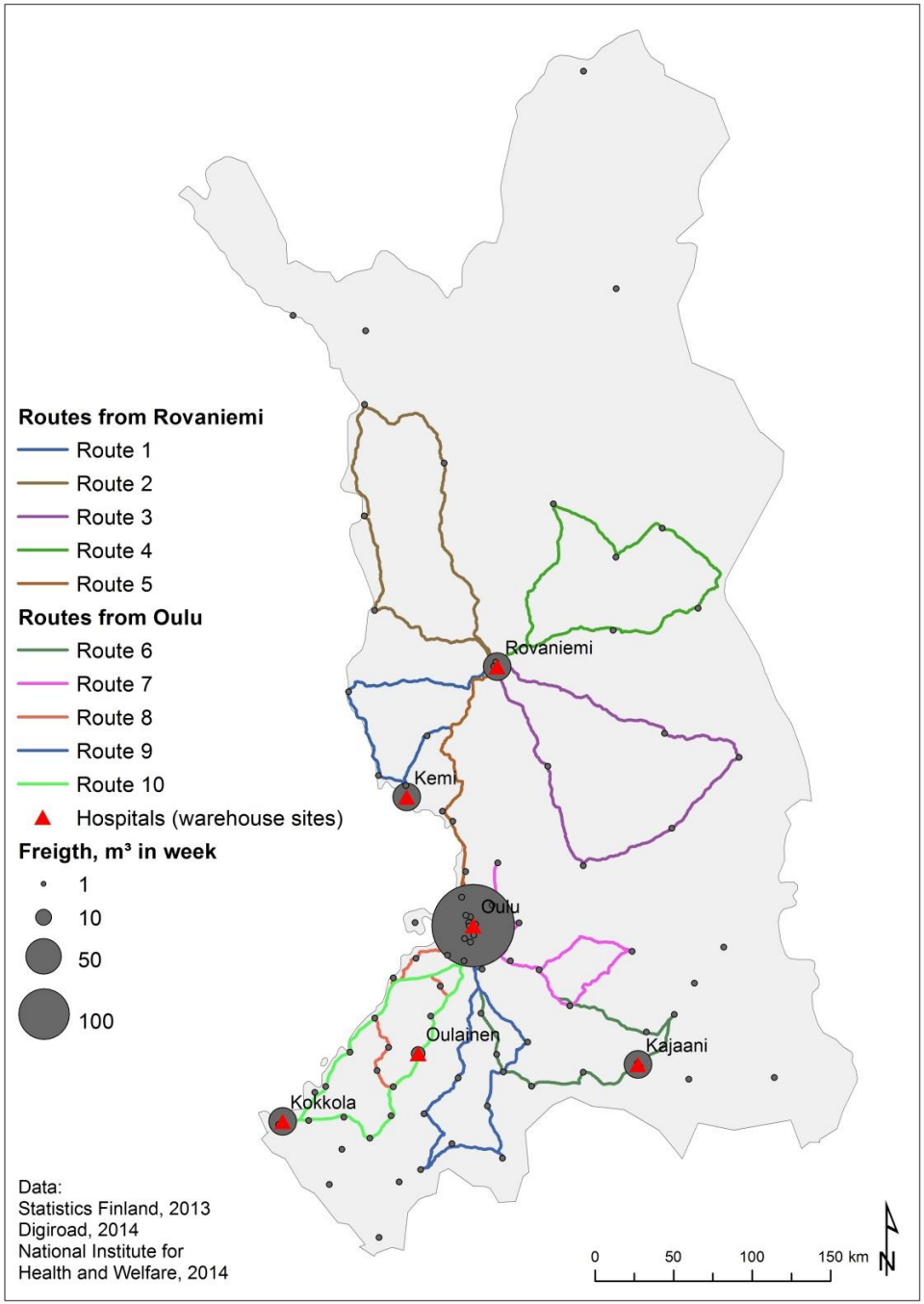
MAJORITY OF HEALTH CENTERS IN NORTH FINLAND MAY BE REACHED EFFECTIVELY BY CENTRALIZED WAREHOUSING FUNCTIONS

Number of warehouses	Total driving time (hours)	N of accessed health centers
1	74,7	80
2	92,4	91
3	85,6	91
4	83,3	91
5	81,3	91
6	80,8	91



ACCESSIBILITY SCENARIOS WITH 1-6 HUBS AND 52-92 HEALTH CENTERS

Number of warehouses	Number of health centers (hours total driving time / accessed health centers)				
	52	62	72	82	92
1	67,7 / 47	65,4 / 54	73,1 / 64	72,4 / 72	74,7 / 80
2	61,4 / 51	73 / 61	79,3 / 71	82,1 / 81	92,4 / 91
3	55,2 / 51	65,3 / 61	70,6 / 71	75,5 / 81	85,6 / 91
4	53,5 / 51	64,8 / 61	69,2 / 71	72,5 / 81	83,3 / 91
5	51,8 / 51	63,6 / 61	66,1 / 71	72,1 / 81	81,3 / 91
6	52 / 51	63 / 61	66,7 / 71	70,5 / 81	80,8 / 91

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CONCLUSIONS AND OPENINGS FOR DISCUSSION

- Number of health centers is possible to be reduced by 10 to 20 and “damage” to accessibility does not increase radically.
- Majority of health centers in North Finland may be reached effectively by ”milk route” based deliveries from two centralized warehouses

- Improvements to the study since submitting the conference paper
  - Delivery routes: wan-speed -> truck-speed.
  - Route generation: forced deliveries -> cost-effectiveness

- How different route solving algorithms form routes?
  - ArgGIS *Vehicle Route Problem* tool uses tabu search metaheuristics -> enhanced potential solution - fast sub-optimal solution.

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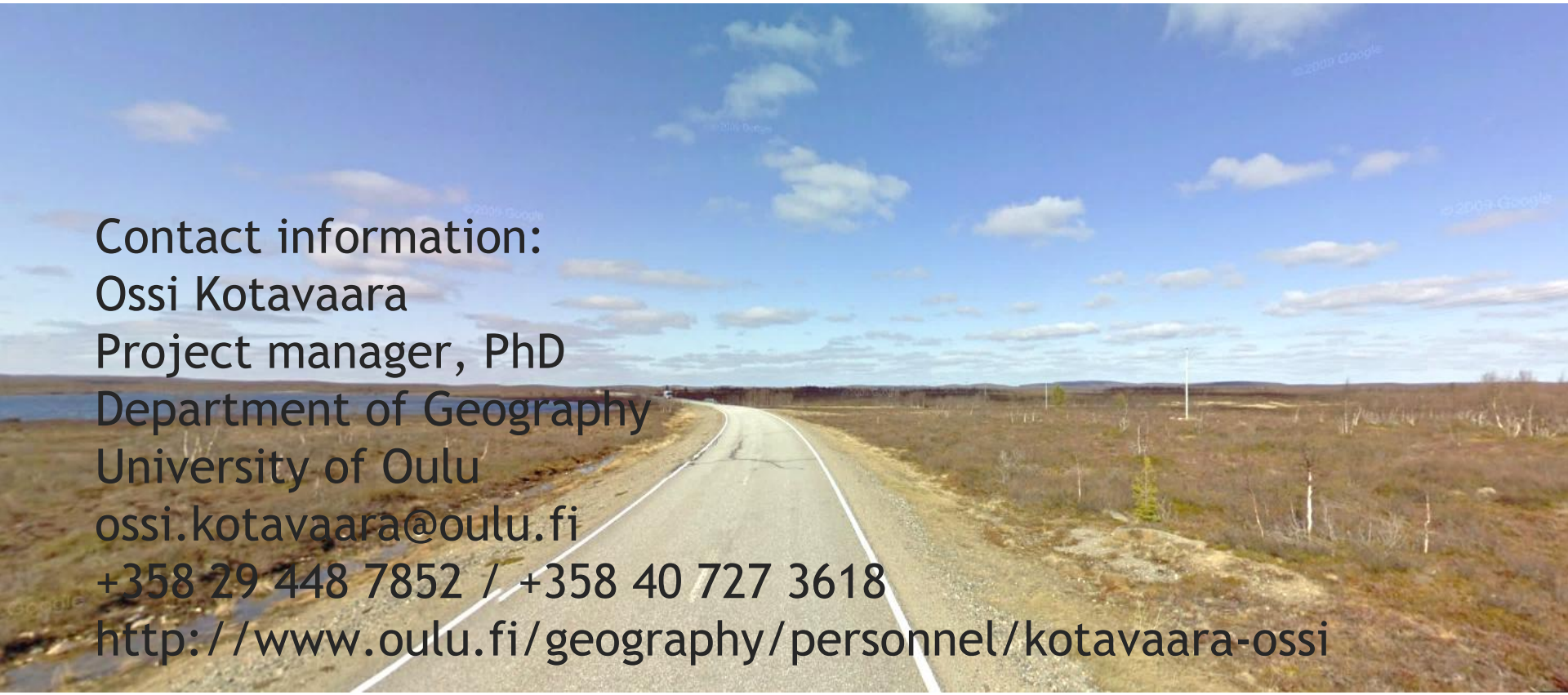
THANK YOU!



Contact information:
Ossi Kotavaara
Project manager, PhD
Department of Geography
University of Oulu
ossi.kotavaara@oulu.fi
+358 29 448 7852 / +358 40 727 3618
http://www.oulu.fi/geography/personnel/kotavaara-ossi

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