Web-tool for optimizing locations of health centers

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IMPRO

Parempi tietopohja &
palvelujen optimointi
sote-uudistuksen tueksi

SiunSote

Stemi

This collection shows heart patients/hospitals in whole Finland, and time to travel to nearest location for each patient

UEF //
MACHINE
LEARNING

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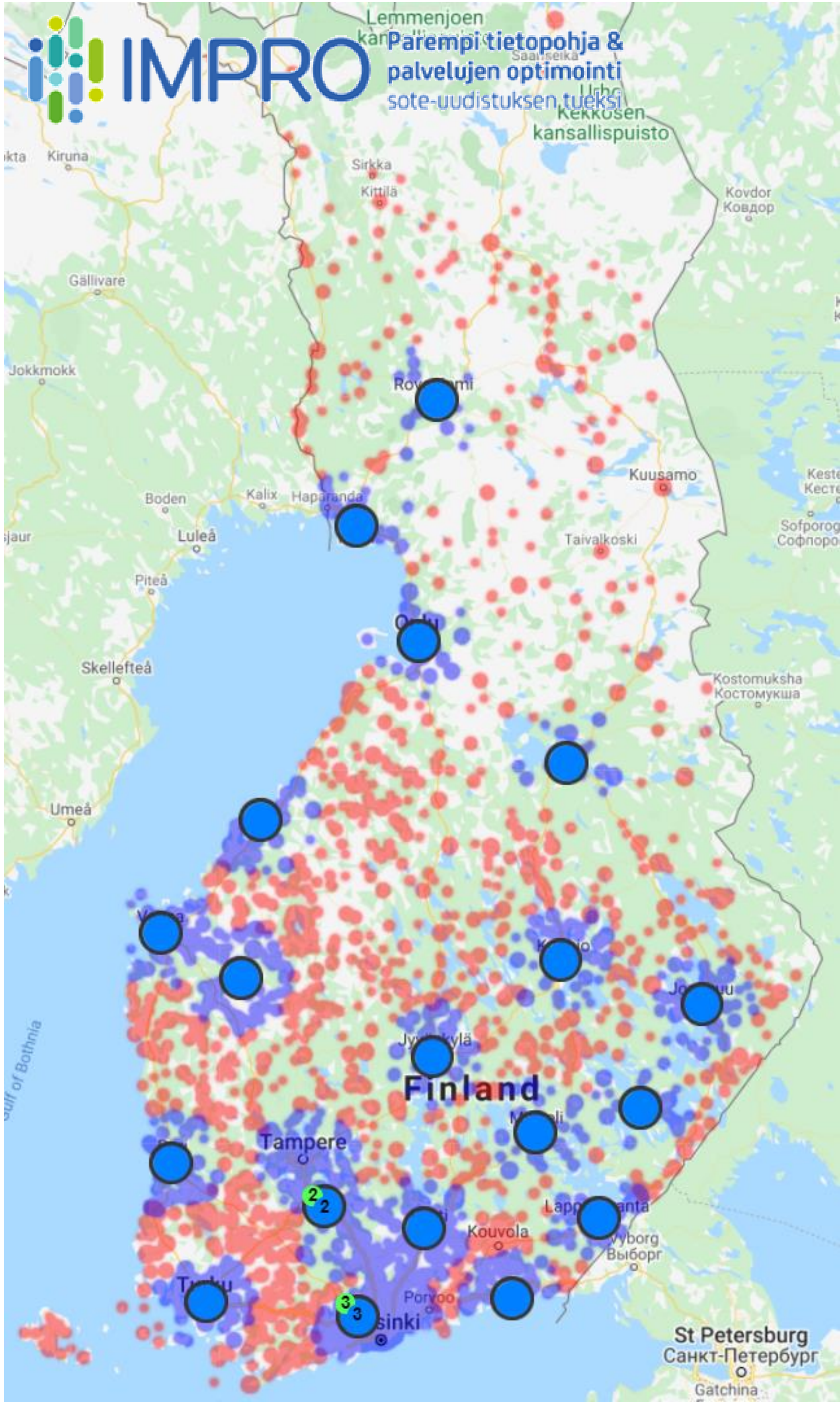
EASTERN FINLAND

thl

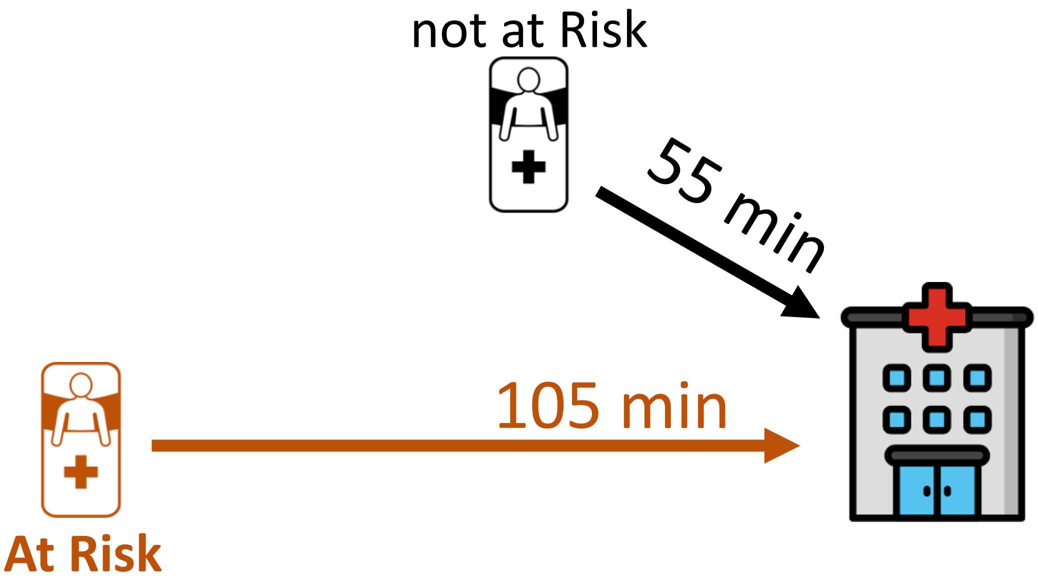
STEMI case study

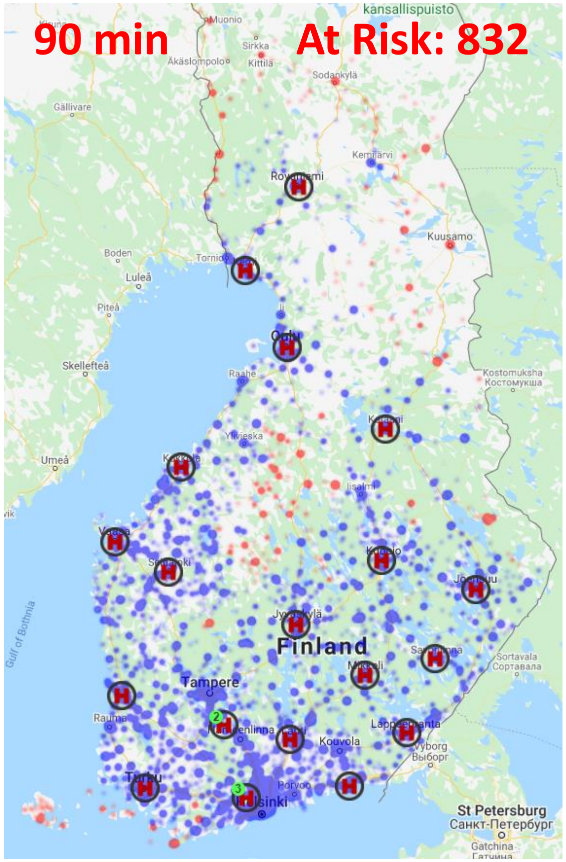
- 22 Health centers (HC)
- 17346 patients (**ICD10 codes I21.0-I21.3**)
- Patient locations (postal code precision)
- Red patients do not reach HC in time.
- Fast travel-time estimation (almost ready)



Who is at Risk (90 min)?

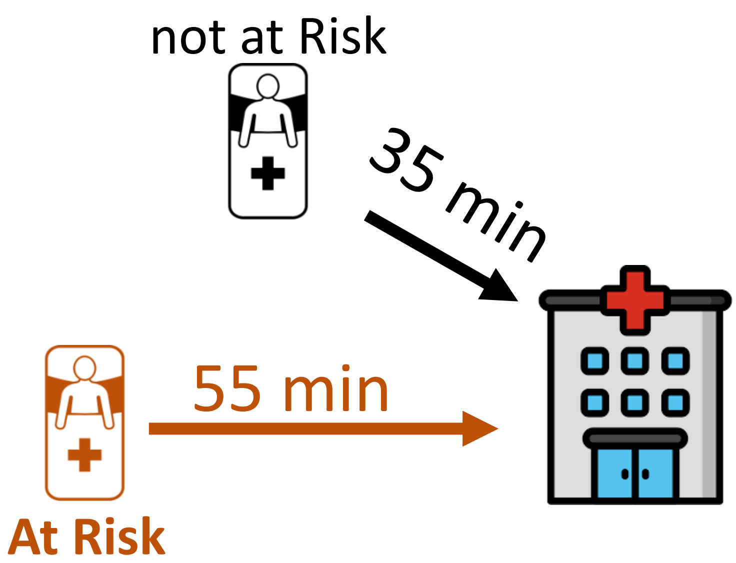
Infarctions are serious and **life threatening**.
A patient not within **90** minutes of a hospital is considered at Risk.

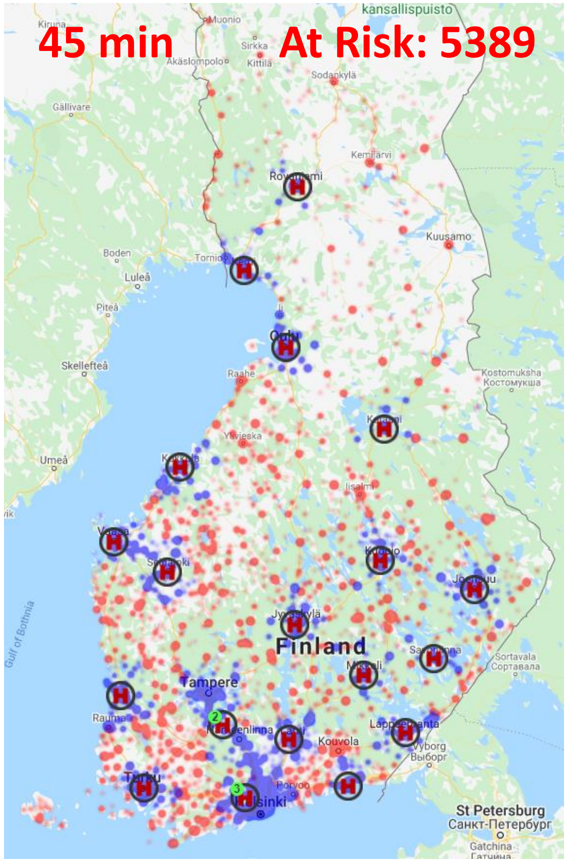




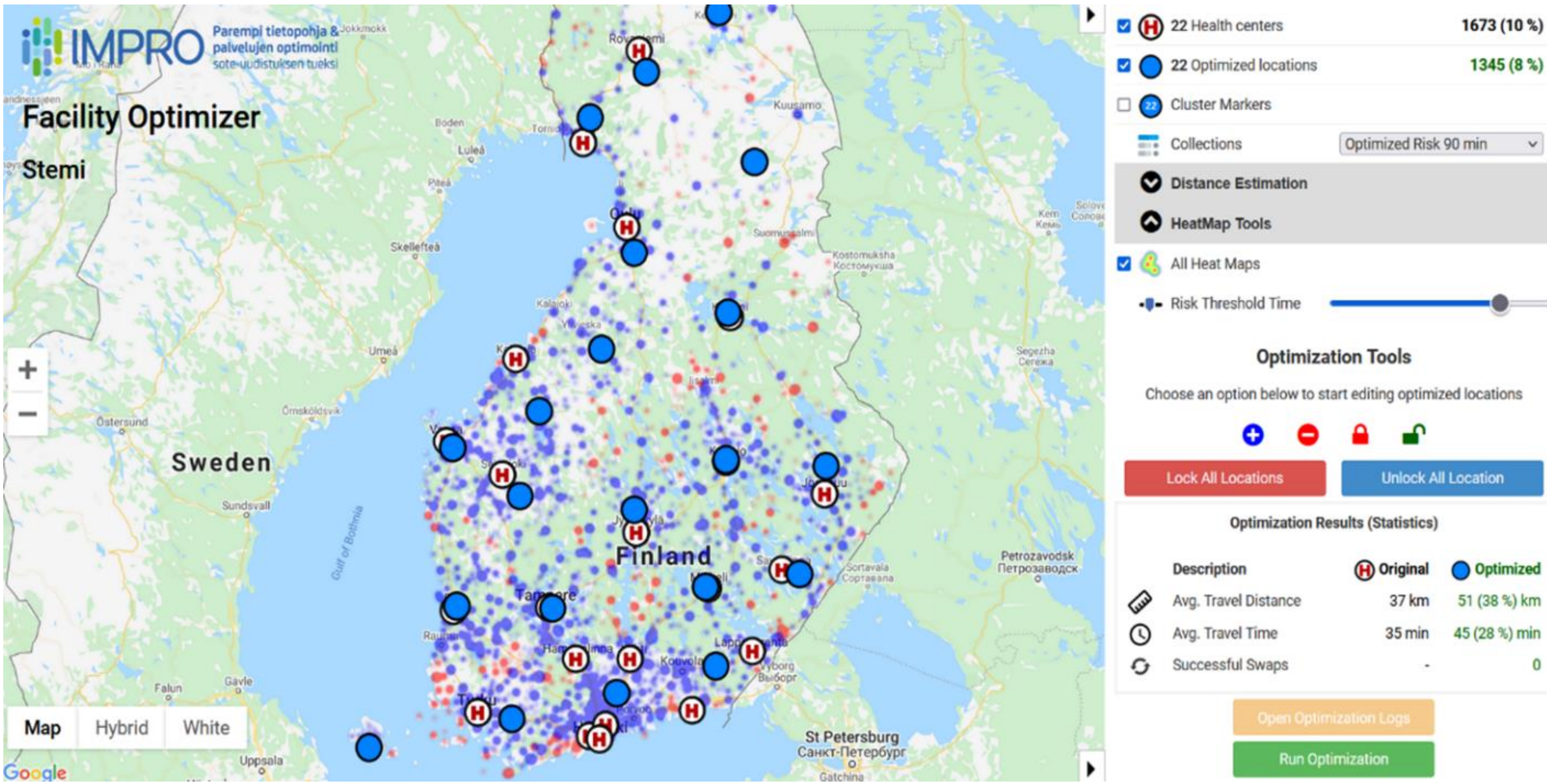
Tighter bound (45 min)

Infarctions are serious and **life threatening**.
A patient not within **45** minutes of a hospital is considered at Risk.



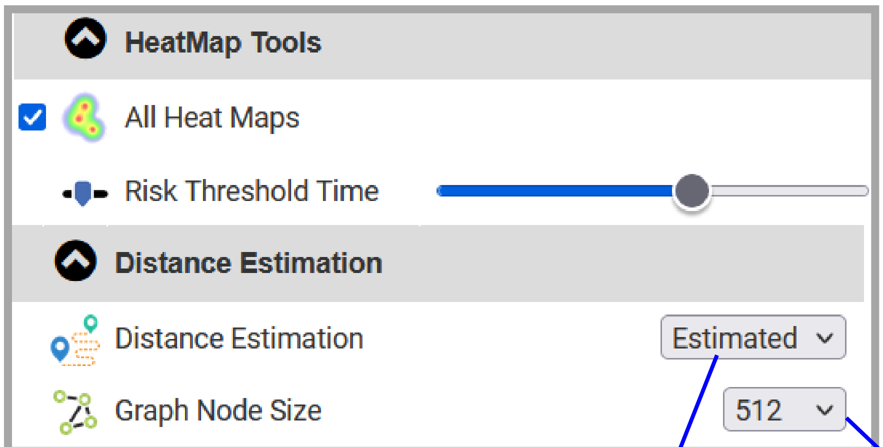


Web-tool for optimizing

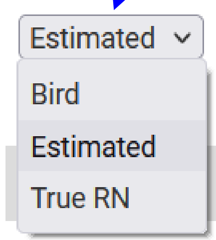


Control parameters

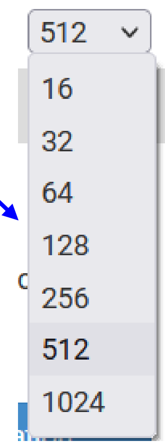
Parameter choices in the tool :



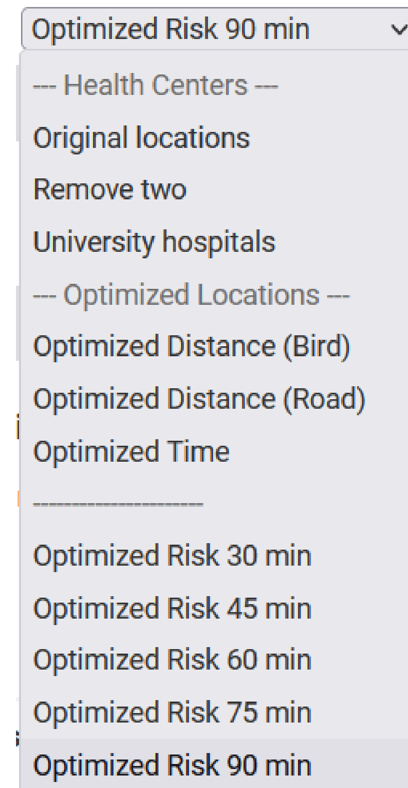
Distance functions:



Graph size:



Optimization goal:



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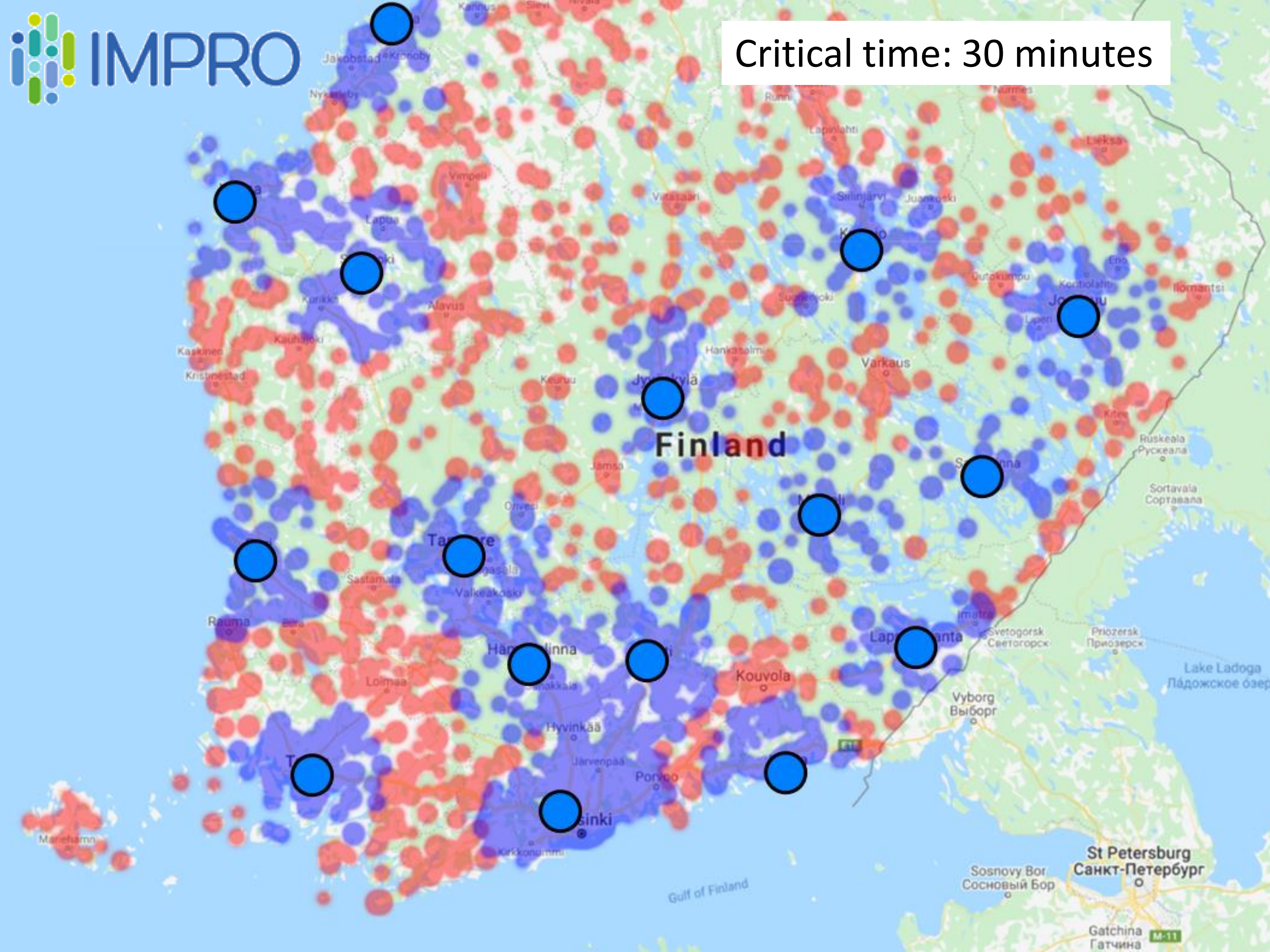
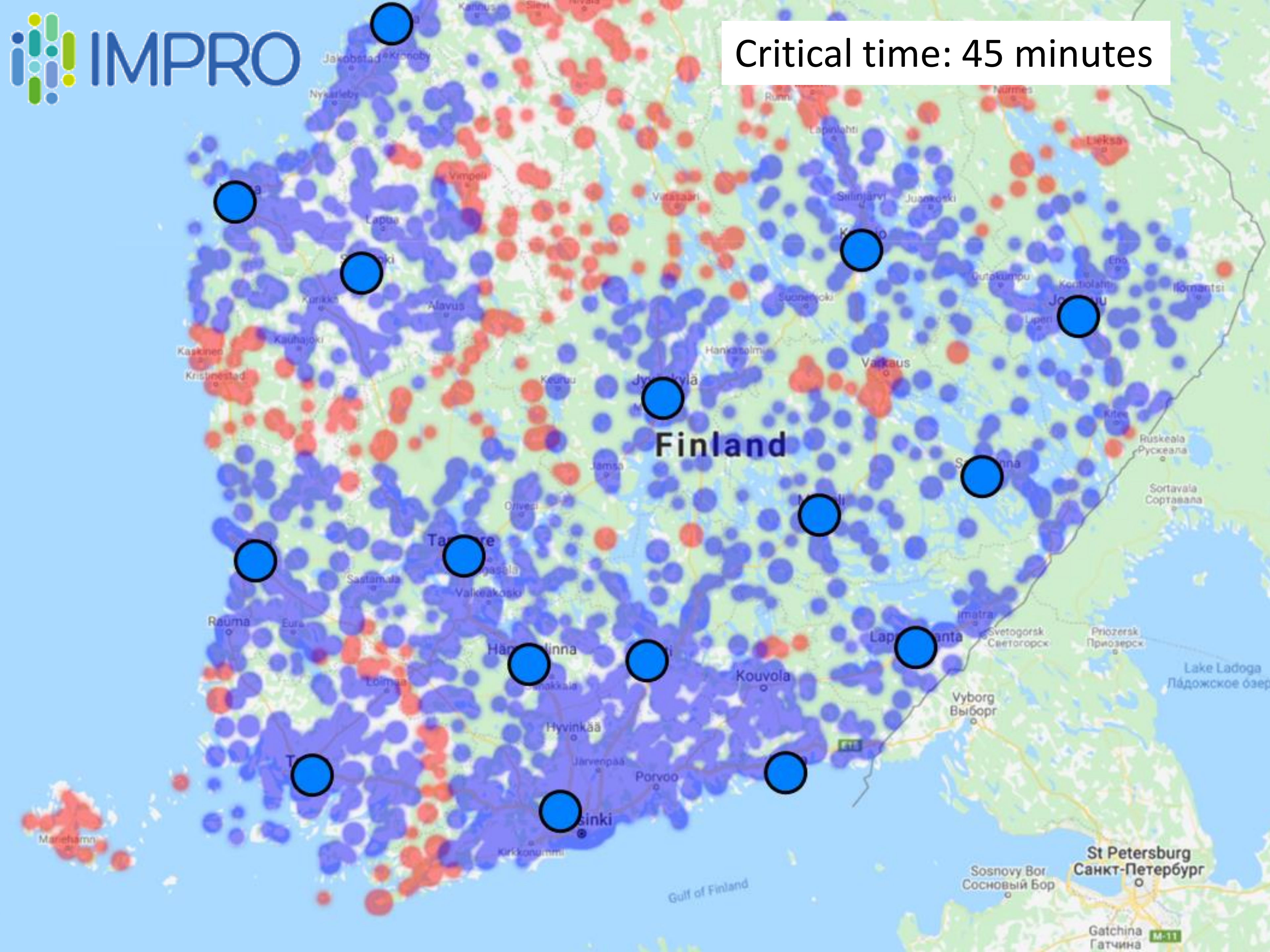
Critical time: 30 minutes



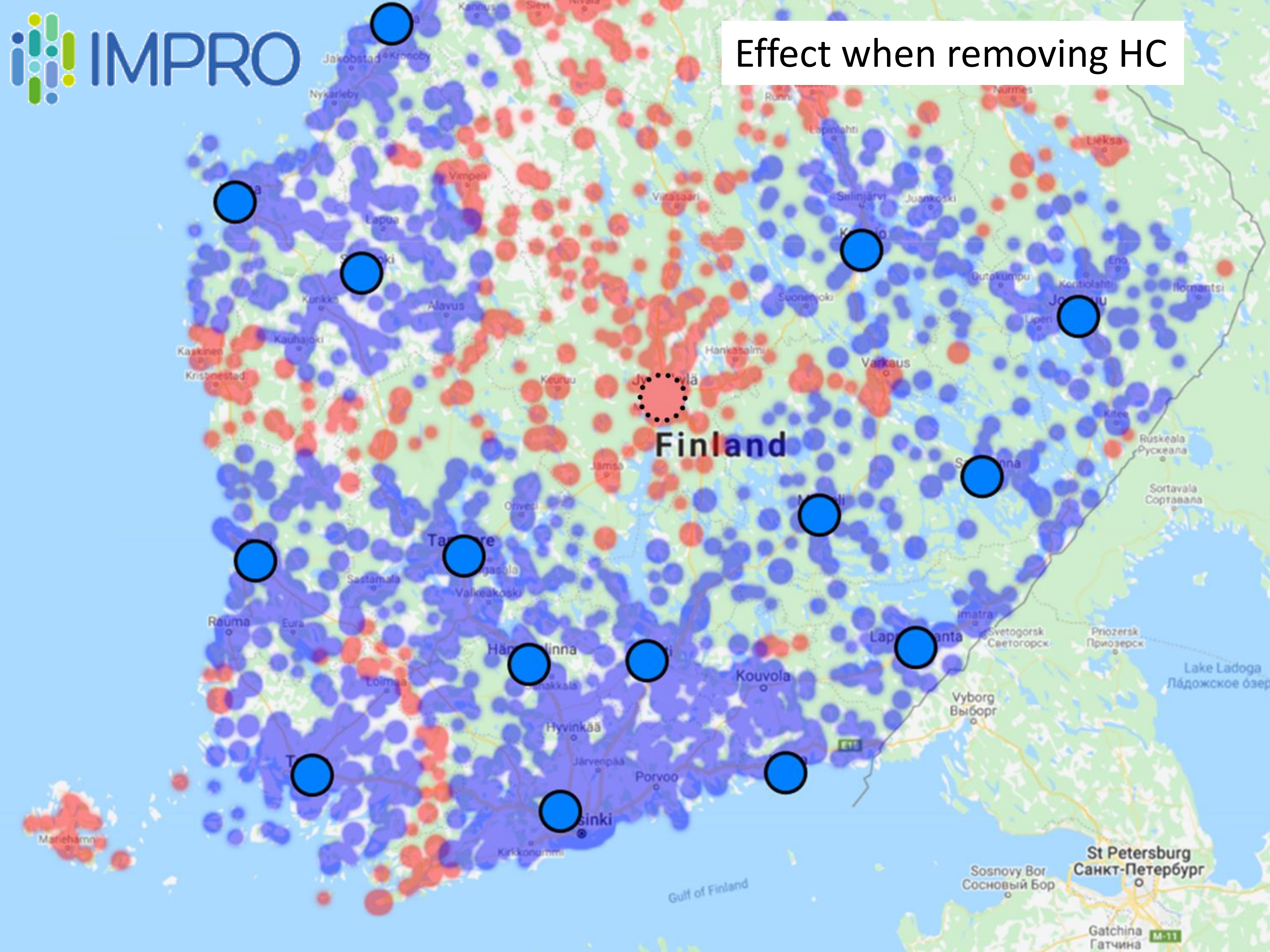
IMPRO

Critical time: 45 minutes

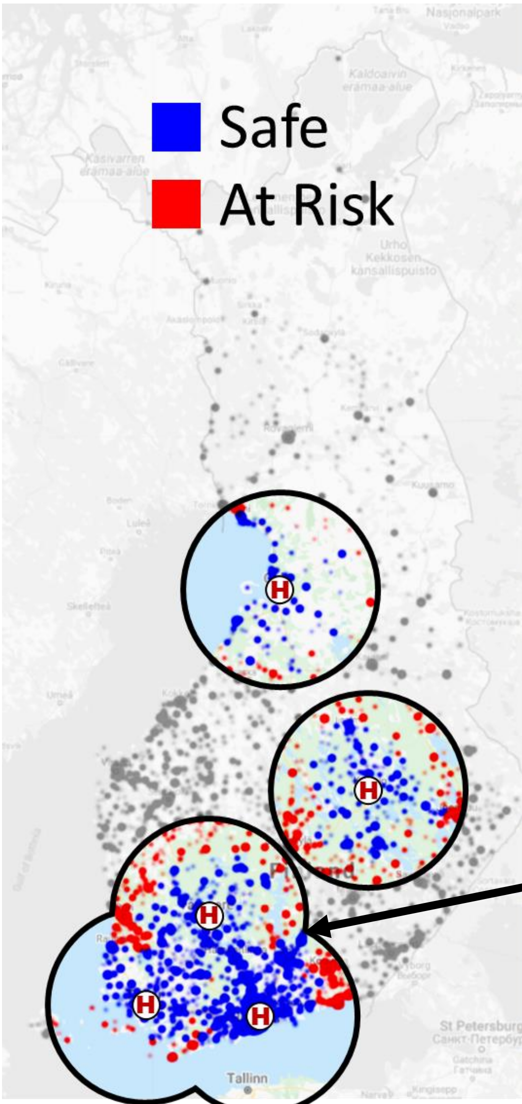


IMPRO

Effect when removing HC

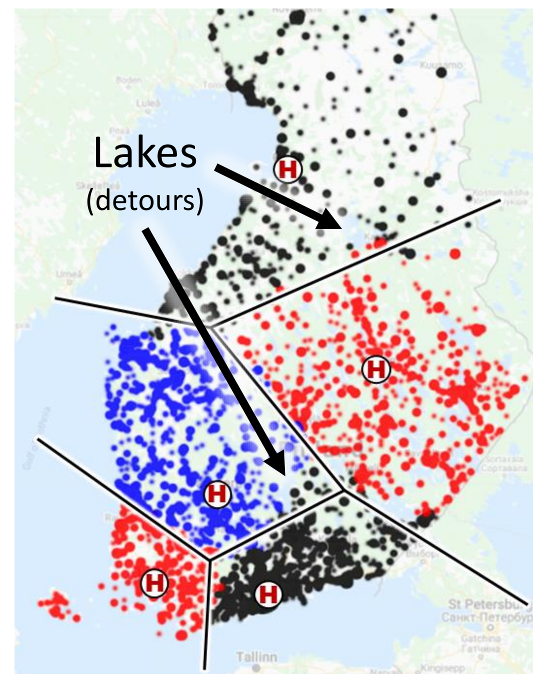


University hospital clusters

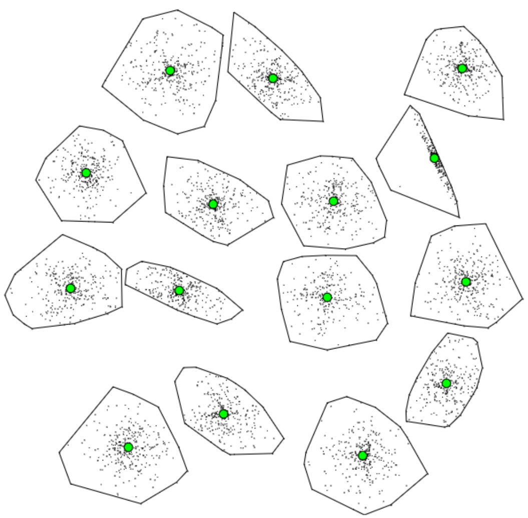


Road infrastructure
supports furthest reach

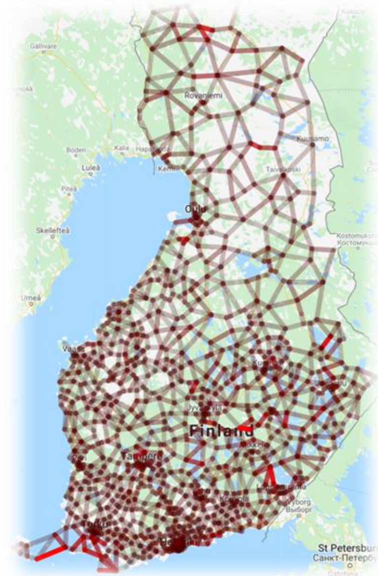
Patients nearest H
Is not always the best choice



Optimization Procedure

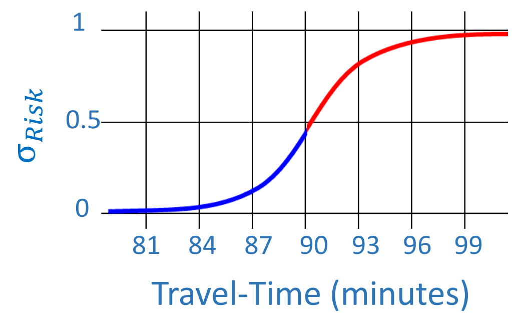


Random Swap Algorithm



Fast Travel-Time Estimation

$$\sigma_{Risk}(x) = \frac{1}{1 + e^{-x+90}}$$



Objective function

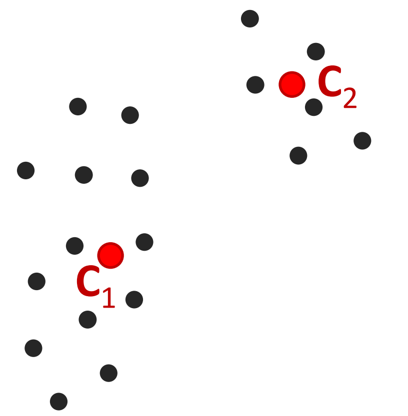
P. Fränti
Efficiency of random swap clustering
Journal of Big Data, 2018.

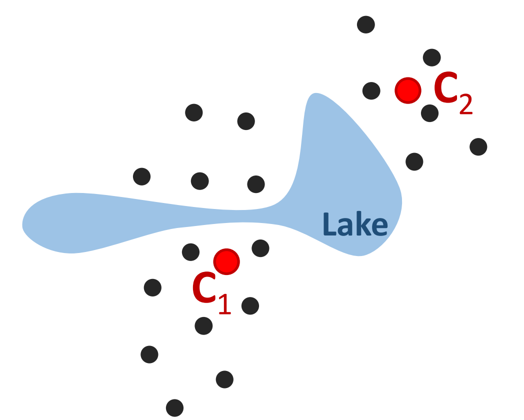
R. Mariescu-Istodor and P. Fränti
Estimating travel-cost using an Overhead Graph
Journal of Location-based Services, 2021.

K-Means

```
K-Means (P, K) → (C, L)
   Input : points P = {p_1,...,p_N}
           the number of clusters K
   Output: cluster centers C = {c_1,...,c_K}
           cluster labels  L = {label(i), i=1,...,N}

   Randomly choose K initial centers C = {c_1,...,c_K}
   REPEAT
   C_previous ← C
   FOR all i ∈ [1, N] DO  // Partitioning
      label(i) ← arg min d(p_i, c_j)
   FOR all j ∈ [1, k] DO  // Centroid update
      c_j ← Average of p_i, whose label(i) = j
   UNTIL C = C_previous
```





K-Means: Partitioning

```
K-Means (P, K) → (C, L)
   Input : points P = {p_1,...,p_N}
           the number of clusters K
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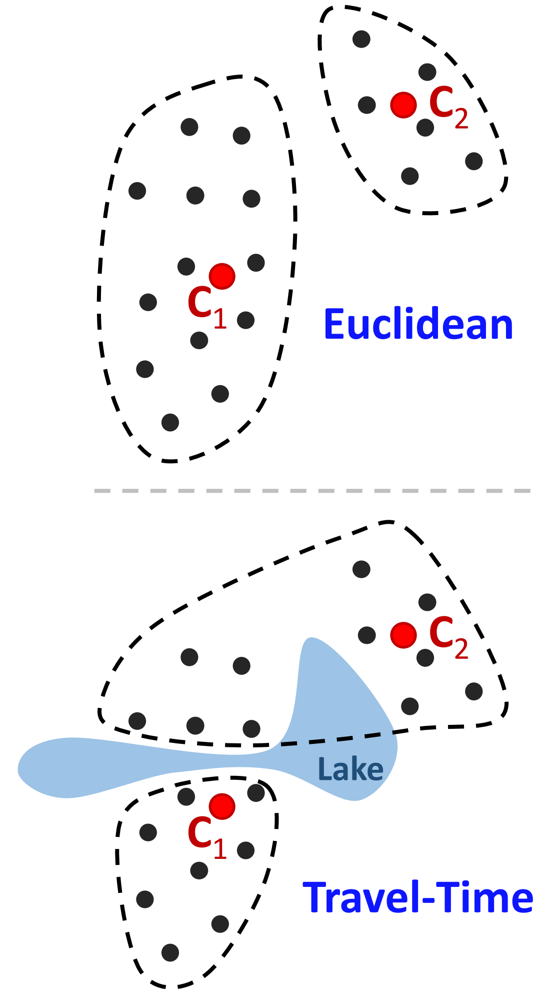
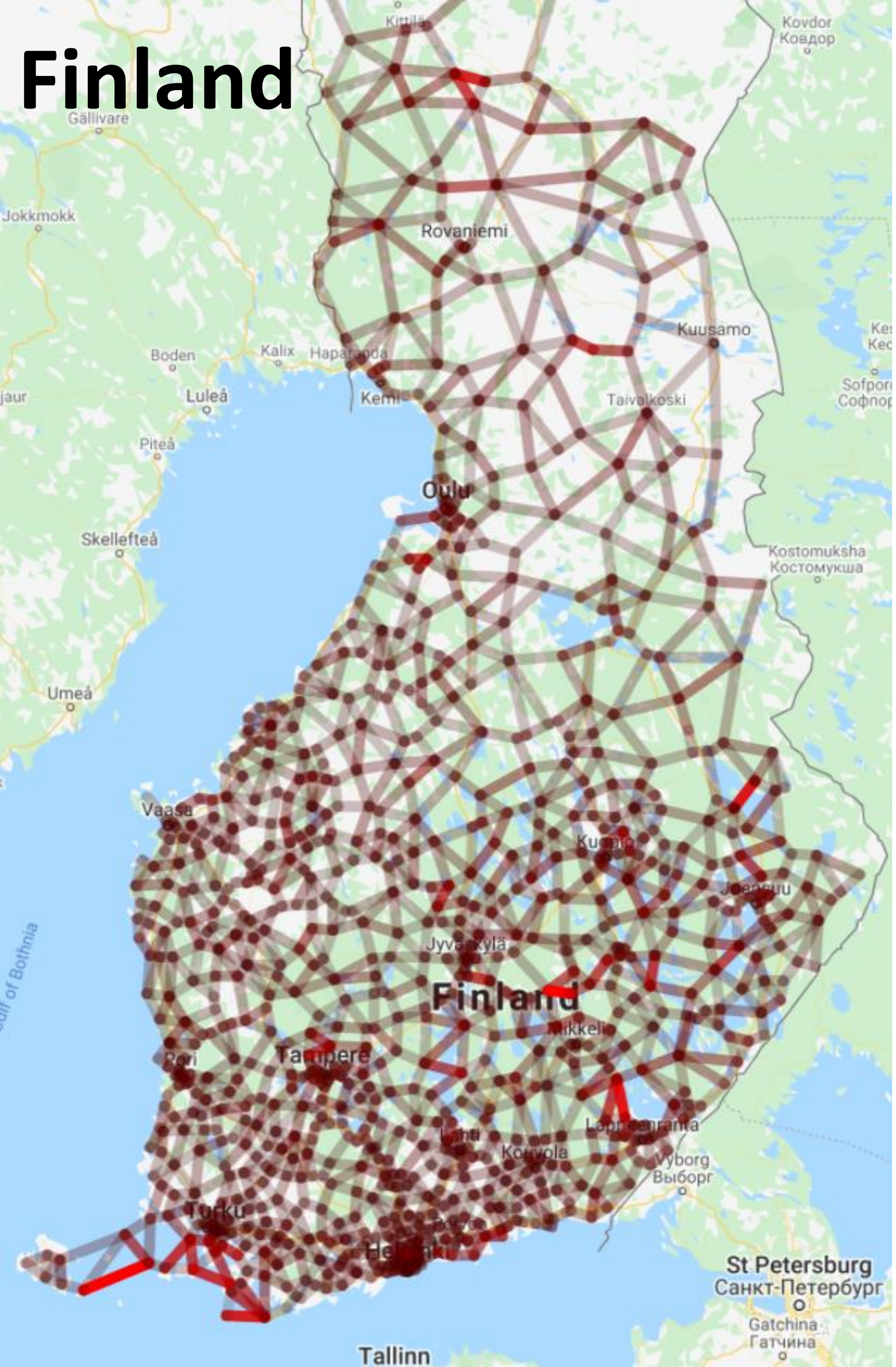
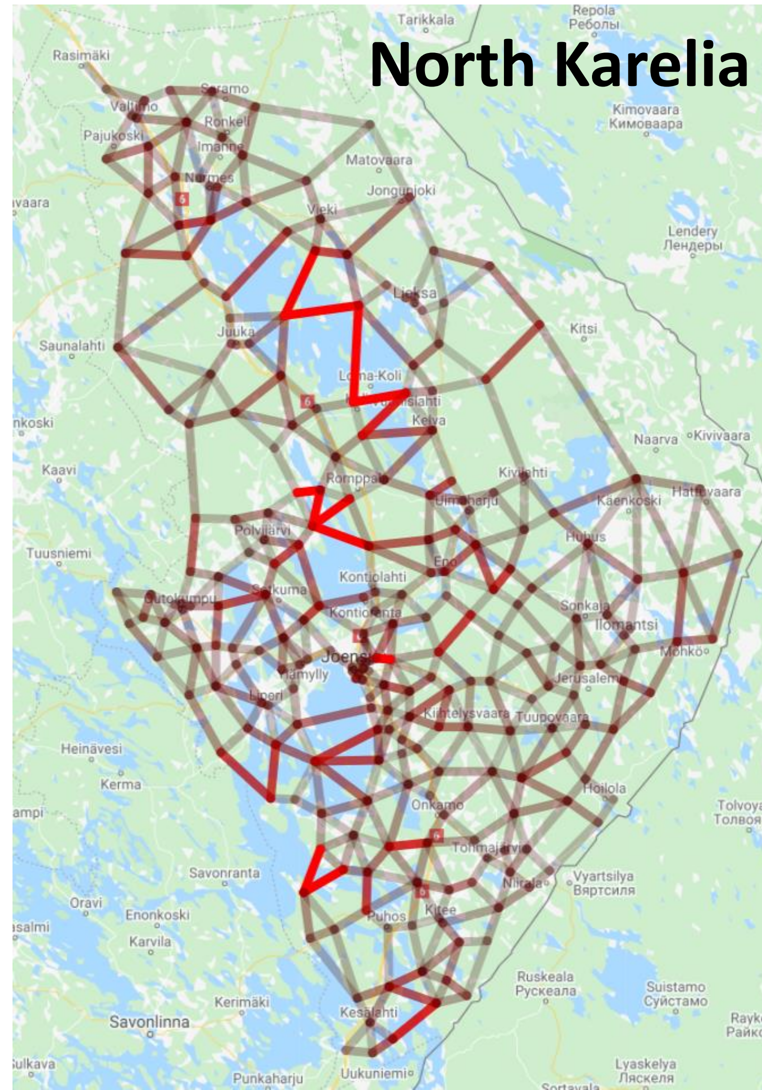


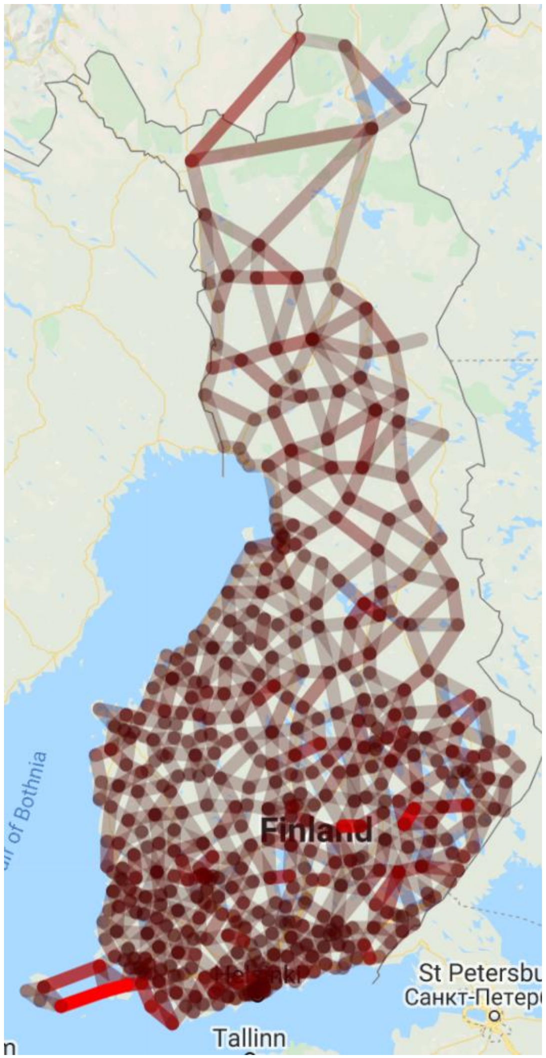
Estimating travel using

Overhead Graphs

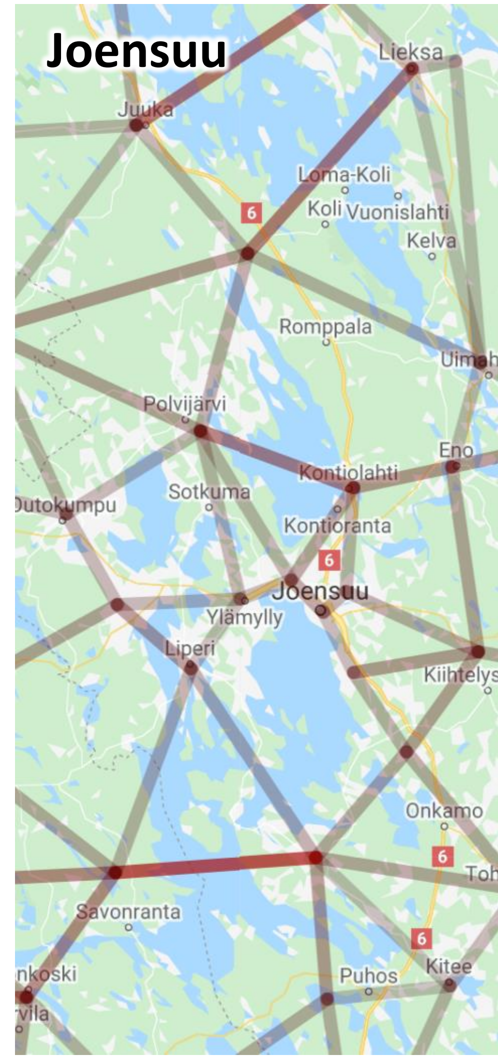




Overhead Graph: Node density

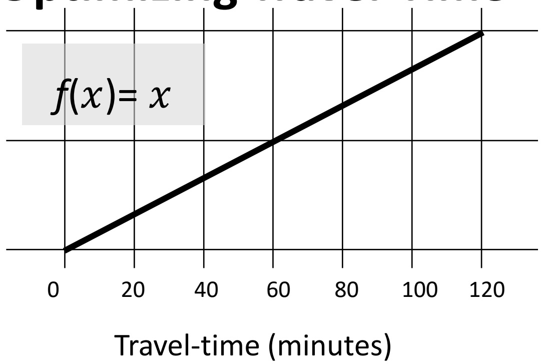


512 nodes

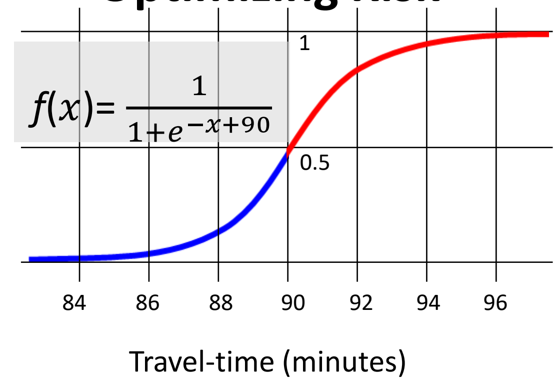


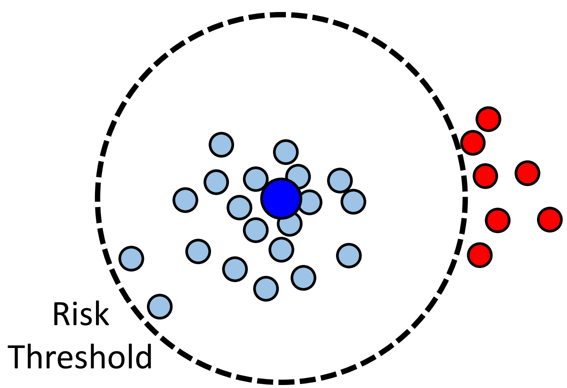
Two cost functions

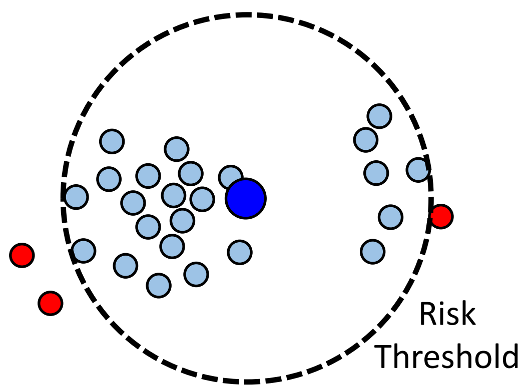
Optimizing Travel-Time



Optimizing Risk

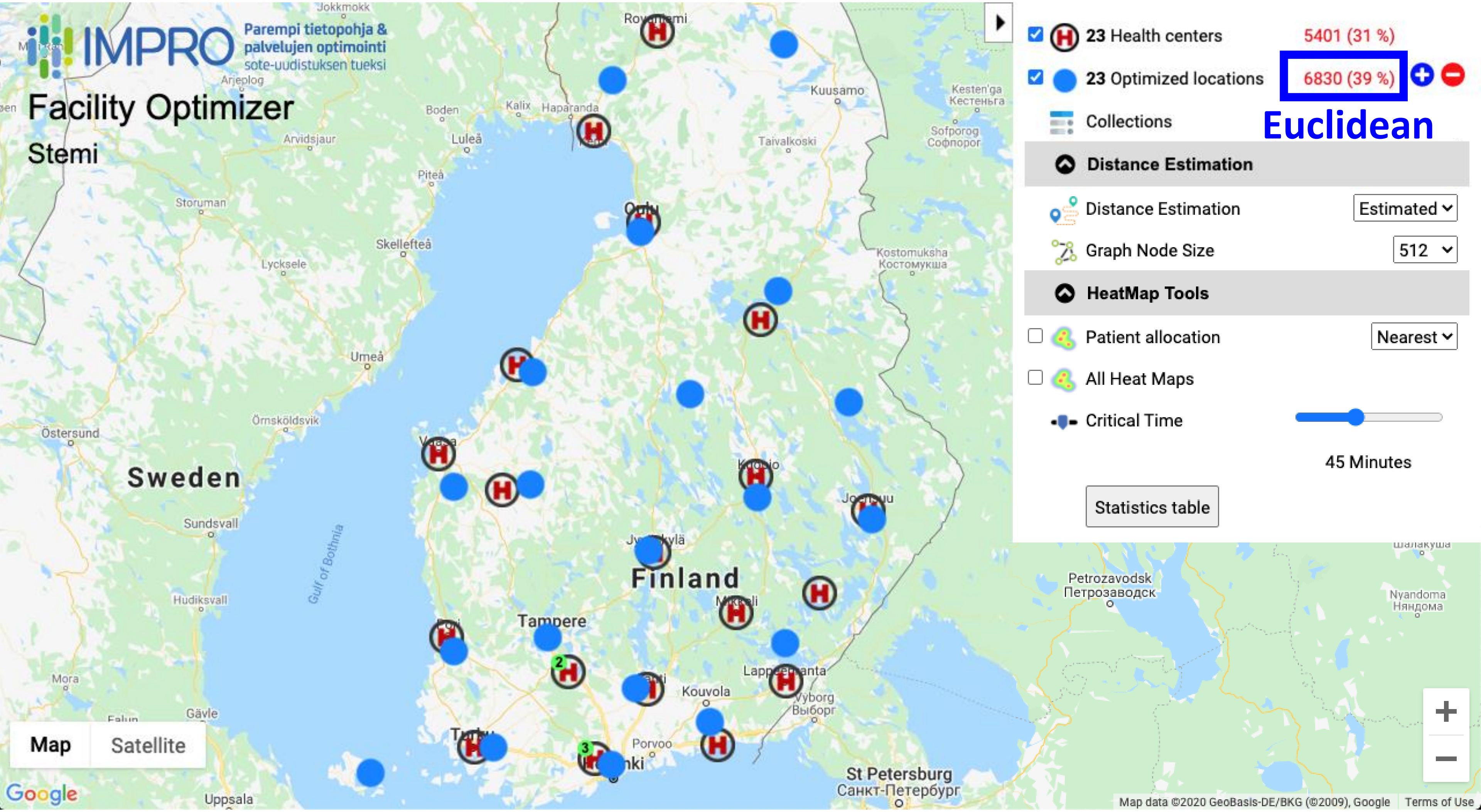




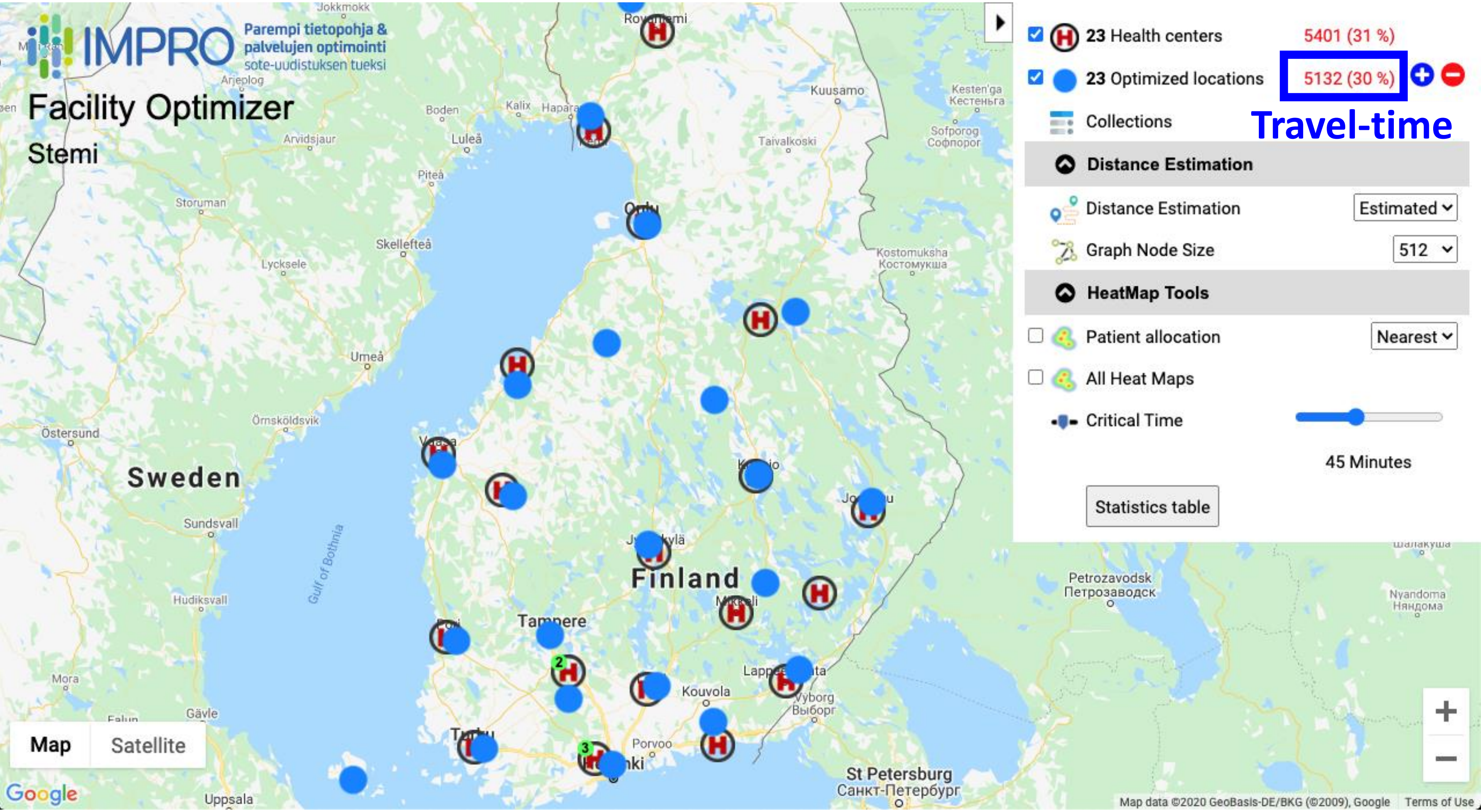


Experiments

Euclidean distance

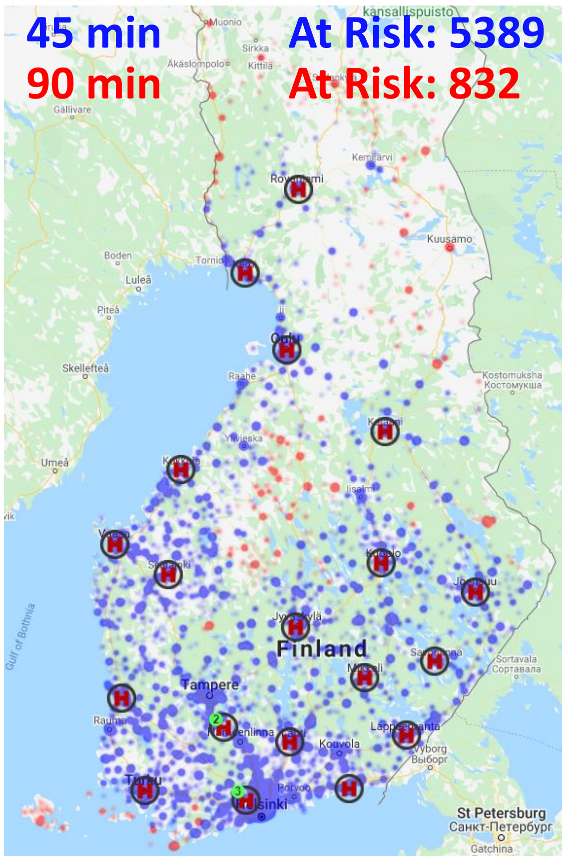


Travel time

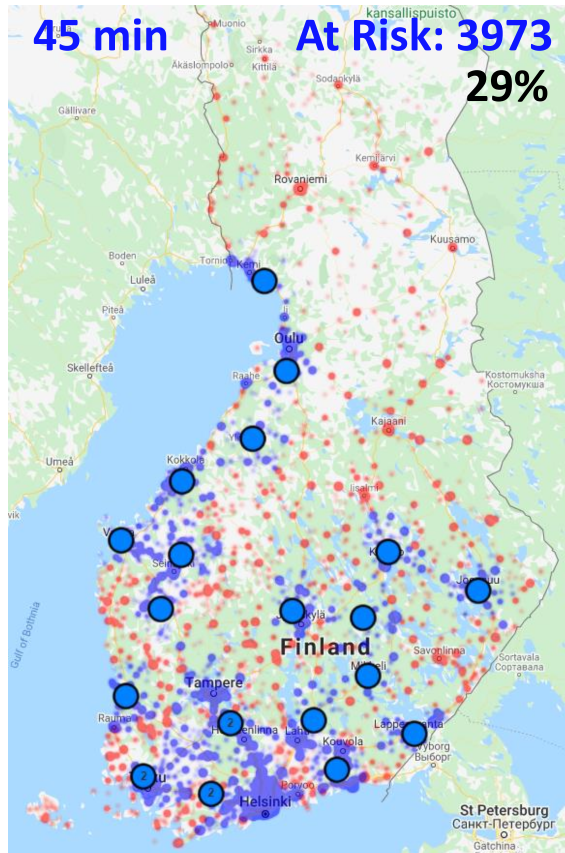

IMPRO
Parempi tietopohja &
palvelujen optimointi
sote-uudistuksen tueksi
Facility Optimizer
Stemi
23 Health centers
5401 (31 %)
23 Optimized locations
5132 (30 %)
Collections
Travel-time
Distance Estimation
Distance Estimation
Estimated
Graph Node Size
512
HeatMap Tools
Patient allocation
Nearest
All Heat Maps
Critical Time
45 Minutes
Statistics table
Sweden
Finland
Tampere
Kouvola
Porvoo
St Petersburg
Petrozavodsk
Kuusamo
Taivalkoski
Luleå
Boden
Kalix
Piteå
Skellefteå
Umeå
Örnsköldsvik
Östersund
Sundsvall
Hudiksvall
Gävle
Uppsala
Mora
Storuman
Lycksele
Arvidsjaur
Arjeplog
Jokkmokk
Gulf of Bothnia
Map
Satellite
Google
Map data ©2020 GeoBasis-DE/BKG (©2009), Google
Terms of Use

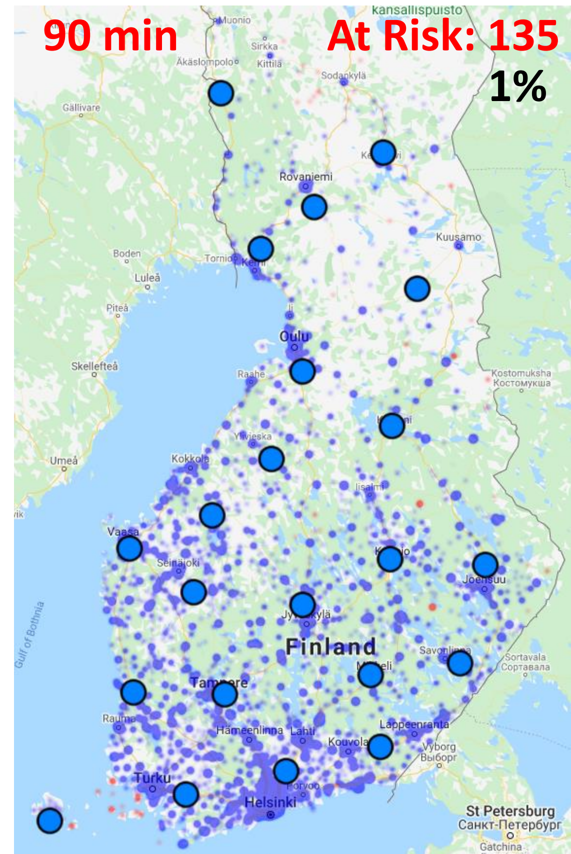
Optimization results

Current Locations



Optimized Locations





Summary of results

	Bird Distance	Travel Distance	Travel Time	At Risk
Original HC Locations	29.0 km	36.6 km	35.3 min	**832 (5 %)**
Optimization Function				
Bird Distance or time (fixed speed)	**27.9 km**	36.1 km	36.2 min	792 (5 %)
Travel Distance	28.4 km	**34.7 km**	34.1 min	519 (3 %)
Travel Time	29.8 km	36.8 km	**34.0 min**	488 (3 %)
Sigmoid (Travel Time)	44.3 km	54.9 km	48.6 min	**135 (1 %)**

- Travel times and distances are estimates using the overhead graph

Statistics: Hospitals removed

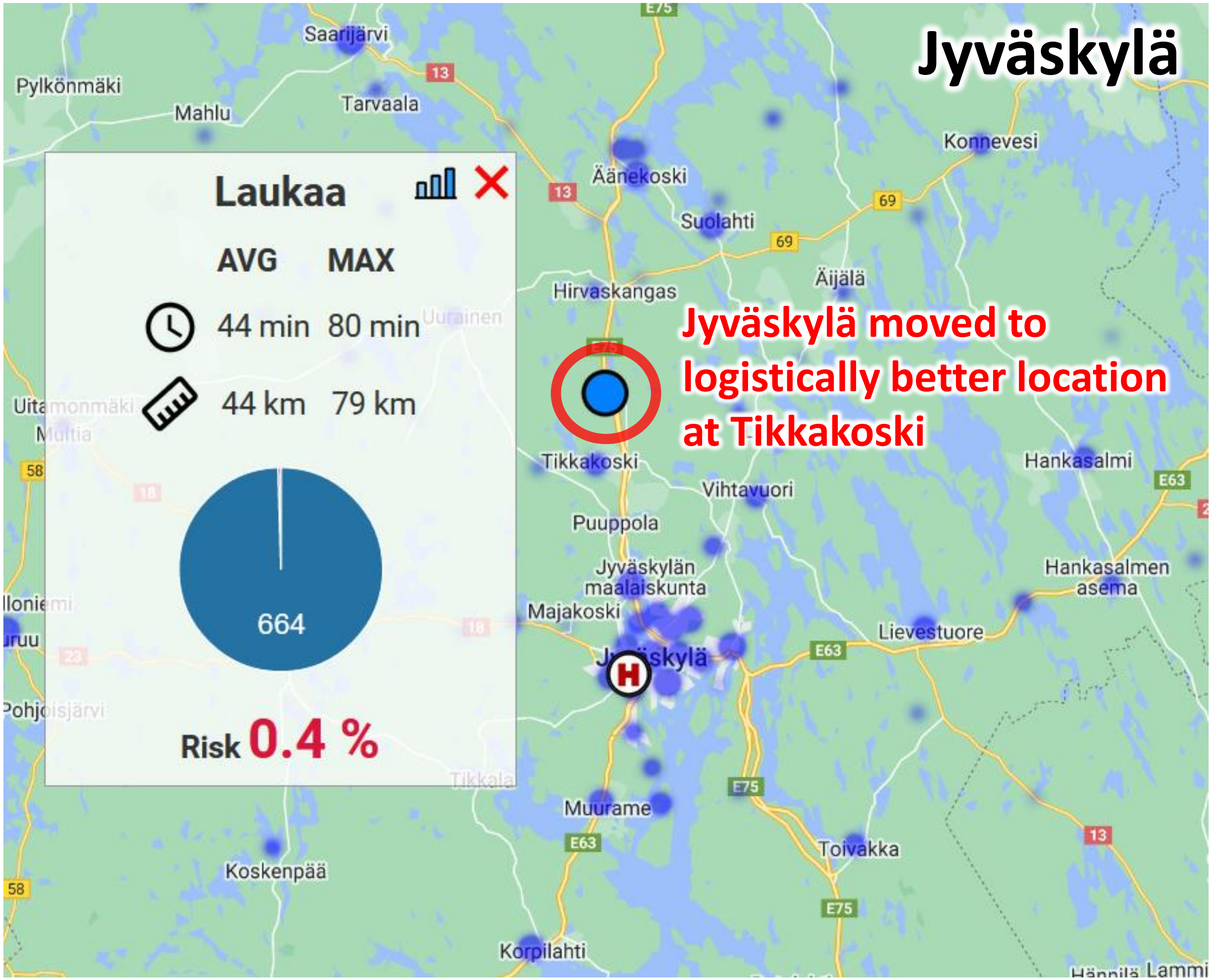
Total patients: 17,346

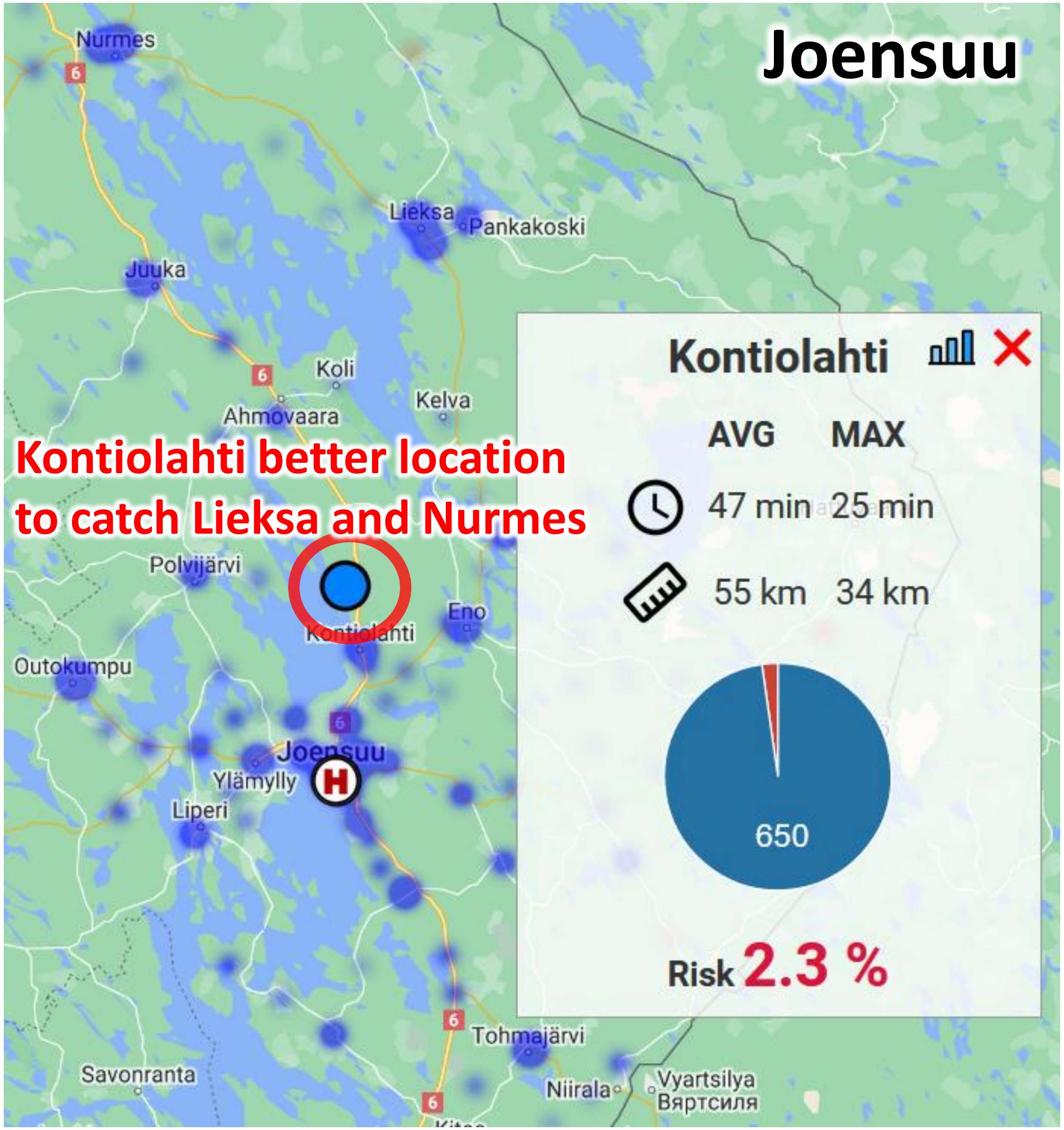
Test-case	At Risk*	Average Travel		Hospitals in Range	
		Time	Distance	1	2+
All Hospitals	5,401 (31 %)	73 min	79 km	51 %	18 %
Two Removed**	5,775 (33 %)	75 min	82 km	49 %	18 %
University hospitals	11,570 (67 %)	121 min	142 km	33 %	0

* Round trip to nearest hospital > 90 minutes

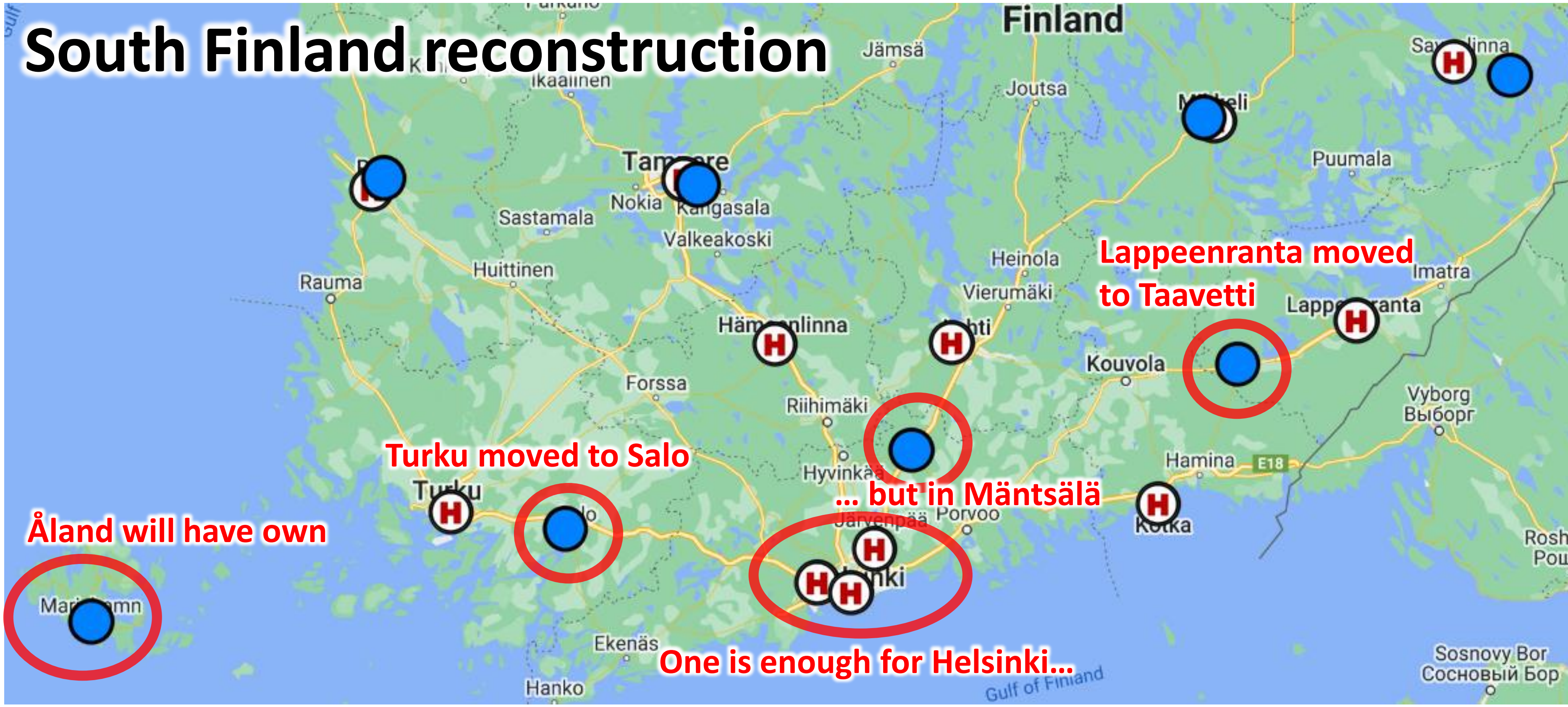
** All Hospitals except Savonlinna and Länsipohja

Changes in detail

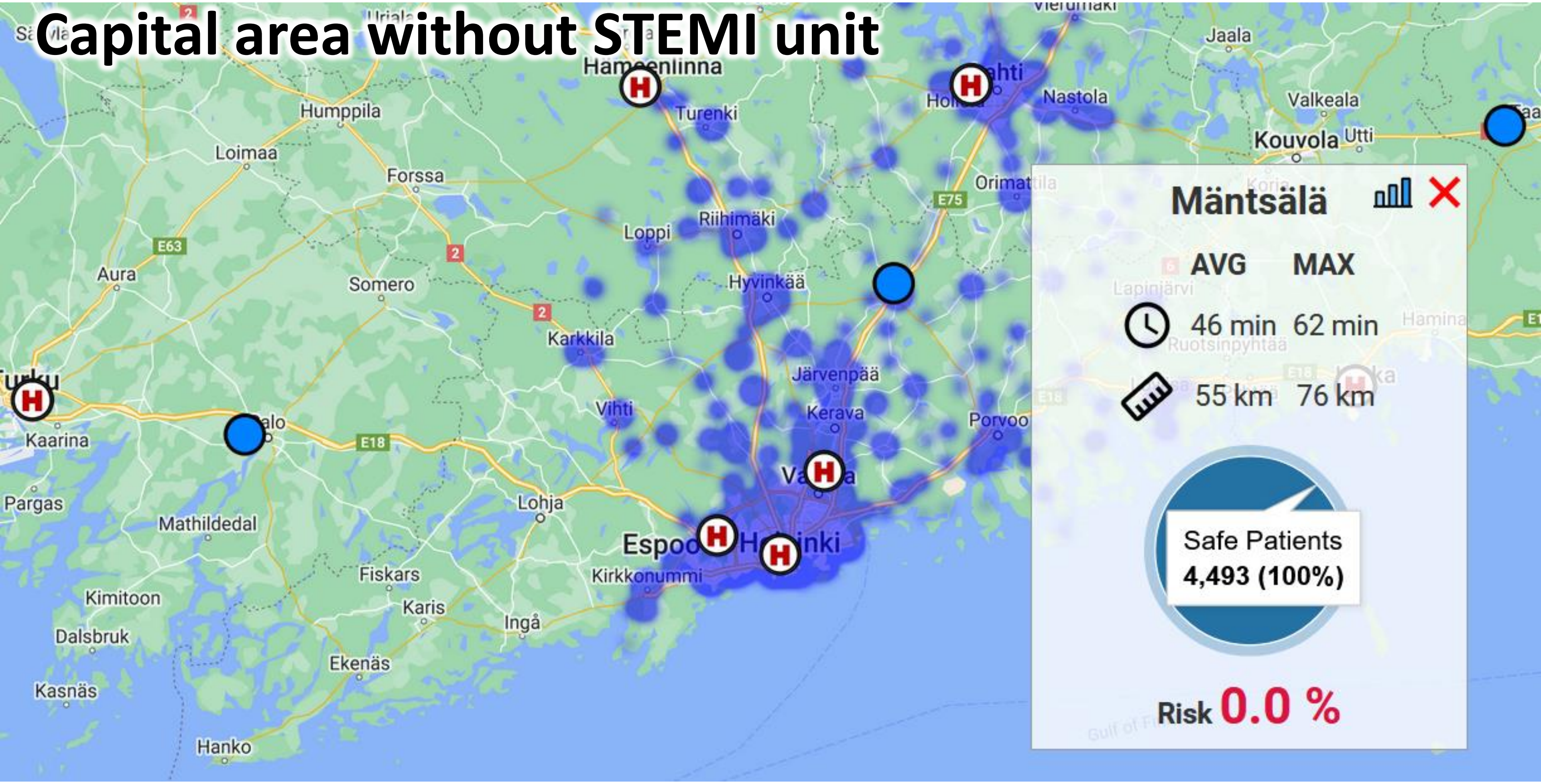

Jyväskylä
Laukaa
AVG MAX
44 min 80 min
44 km 79 km
664
Risk 0.4 %
Jyväskylä moved to logistically better location at Tikkakoski
Saarijärvi
Pylkönmäki
Mahlu
Tarvaala
Äänekoski
Konnevesi
Suolahti
Äijälä
Hirvaskangas
Uurainen
Tikkakoski
Vihtavuori
Hankasalmi
Puuppola
Jyväskylän maalaiskunta
Hankasalmen asema
Majakoski
Lievestuore
Muurame
Toivakka
Koskenpää
Korpilahti
Multia
Tikkala
Pohjoisjärvi
Lammi


Joensuu
Nurmes
Lieksa
Pankakoski
Juuka
Koli
Ahmovaara
Kelva
Kontiolahti better location
to catch Lieksa and Nurmes
Polvijärvi
Kontiolahti
Eno
Outokumpu
Joensuu
Ylämylly
Liperi
Tohmajärvi
Savonranta
Niirala
Vyartsilya
Вяртсиля
Kontiolahti
AVG
MAX
47 min
25 min
55 km
34 km
650
Risk 2.3 %

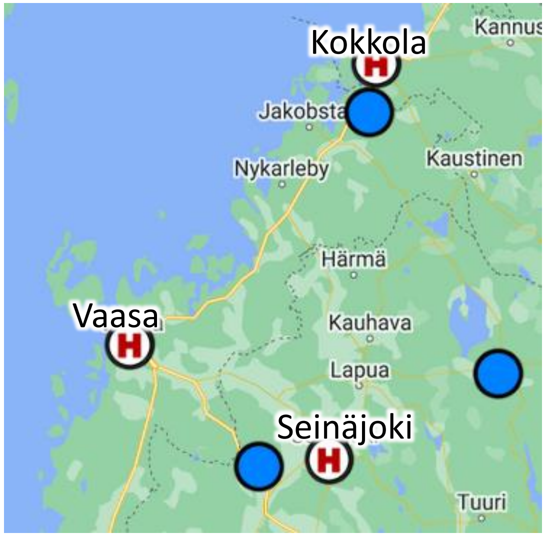
South Finland reconstruction

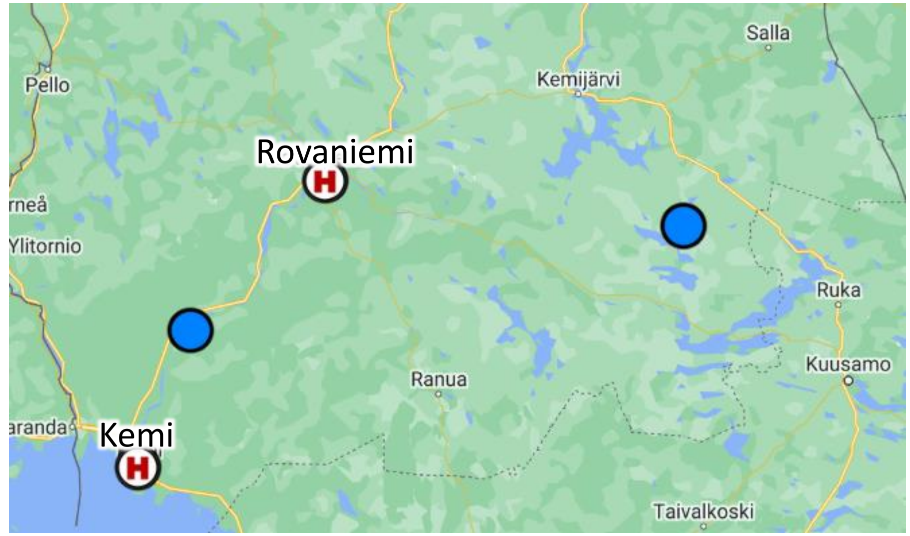


Capital area without STEMI unit

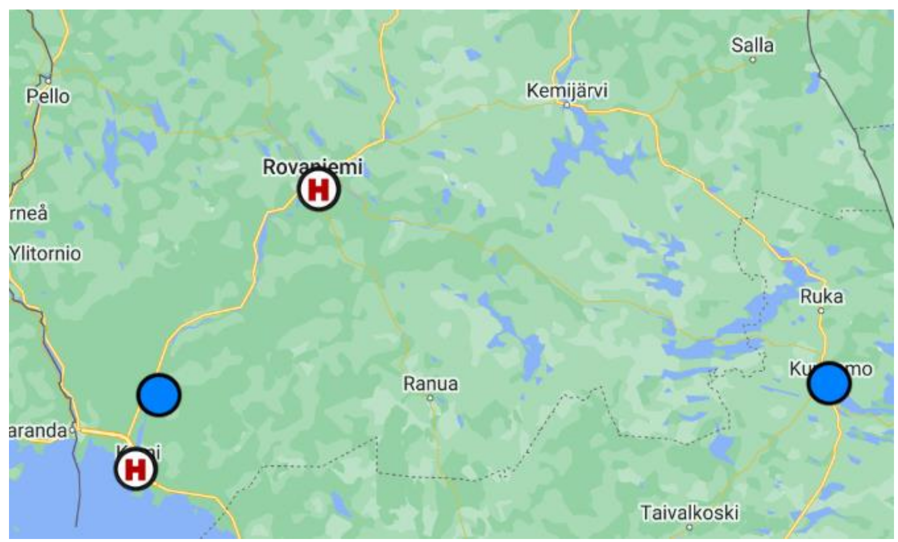


Optimized using Euclidean distance

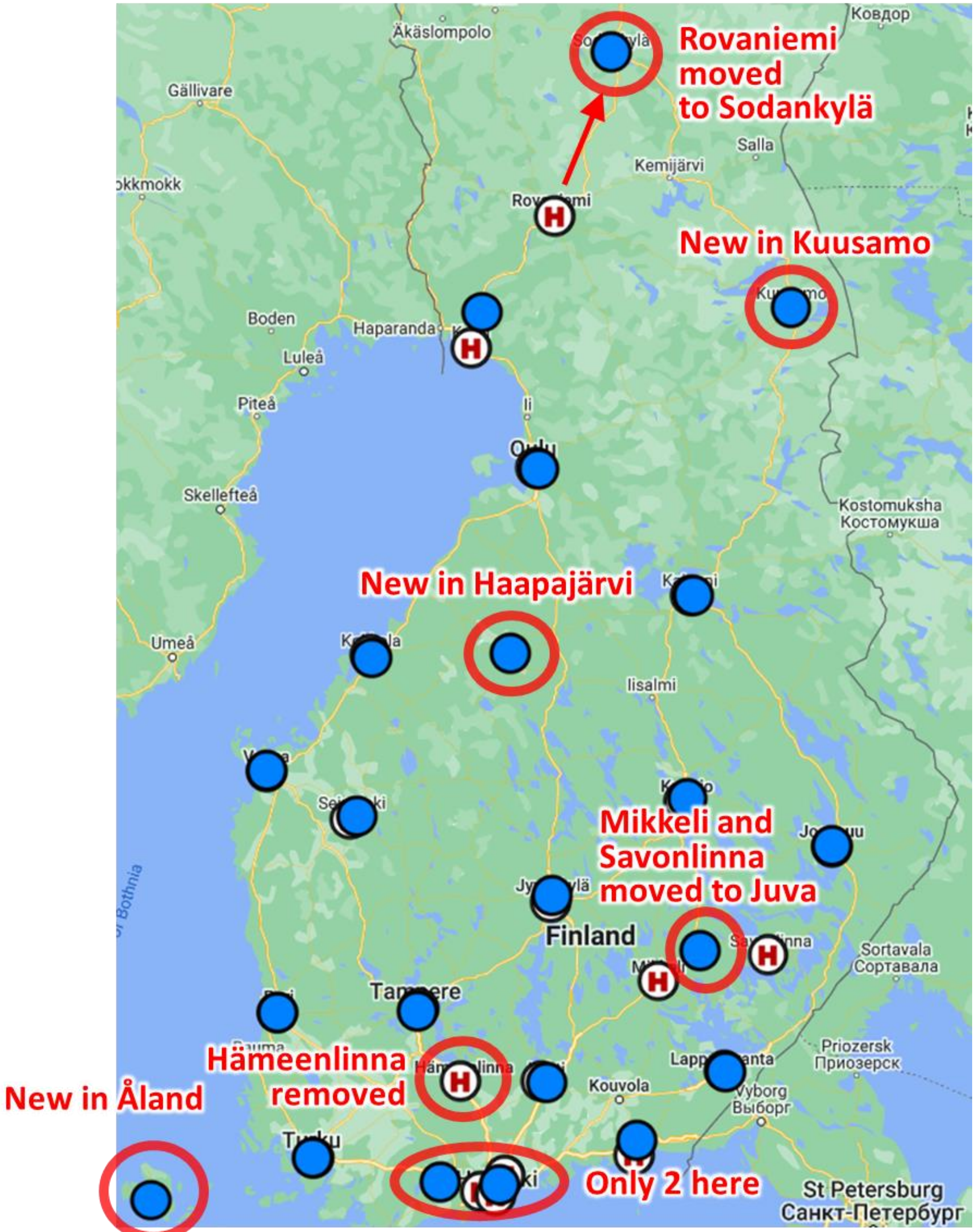




Optimized using travel time



Optimized for travel time



Conclusions

- Web-tool for optimizing health center locations
- Support: Euclidean, travel distance, travel time, patients at risk
- Optimizing for patients at risk increases average time.