EXERCISE 1

Basic Network Functionality

Car accessibility in the Trondheim region

Exercise 1: Basic Network Functionality
Car accessibility in the Trondheim region

1. Tools and Data Used -

1.1. Database –

a) Road Network – Elveg, covering car traffic of Trondheim and neighbouring municipalities

b) Population data as grid points

c) Point feature classes as post office locations

d) Addresses as point feature class

1.2. Tools –

a) Basic ArcGIS tools (Creating, Modifying and Exporting Feature Classes, Layout, Symbology)

b) Basic Database Management tools (Spatial Join, Join, Creating Fields, Summarizing Data)

c) Network Analysis functions (Route, Service Area, Closest Facility, OD Cost Matrix)

d) MS-Excel and MS-Word

1.3. Units –

a) Distance - Meters

b) Time - Minutes

2. Results

2.1. Route Function

The route function can be used to find the optimal shortest/fastest route between two points.

For the analysis, two addresses were chosen as stops and then the shortest and fastest routes were calculated and analysed with different conditions.

Stops: The origin stop was chosen near Steinan while the destination stop was chosen near Lade.

Routes:

2.1.1 Two different routes were calculated when time and distance were minimized (optimized) in the Route Network Analysis.

Fig.1 Shortest and Fastest Routes between two selected points

Shape	Name	FirstStopID	LastStopID	StopCount	Total_Minutes	Total_Length	Shape_Length
Polyline M	Minimized_Distance	3	4	2	12.55	7391.59	7393.32
Polyline M	Minimized_Time	3	4	2	9.97	8380.71	8382.64

The shorter route takes around 2.5 minutes extra to complete the trip compared to the fastest route. This could be because the shortest route goes within the city centre while the fastest route takes the highway.

2.1.2 For the second variation, all one-way and car restrictions were removed while for the third variation, the sequence of stops was reversed.

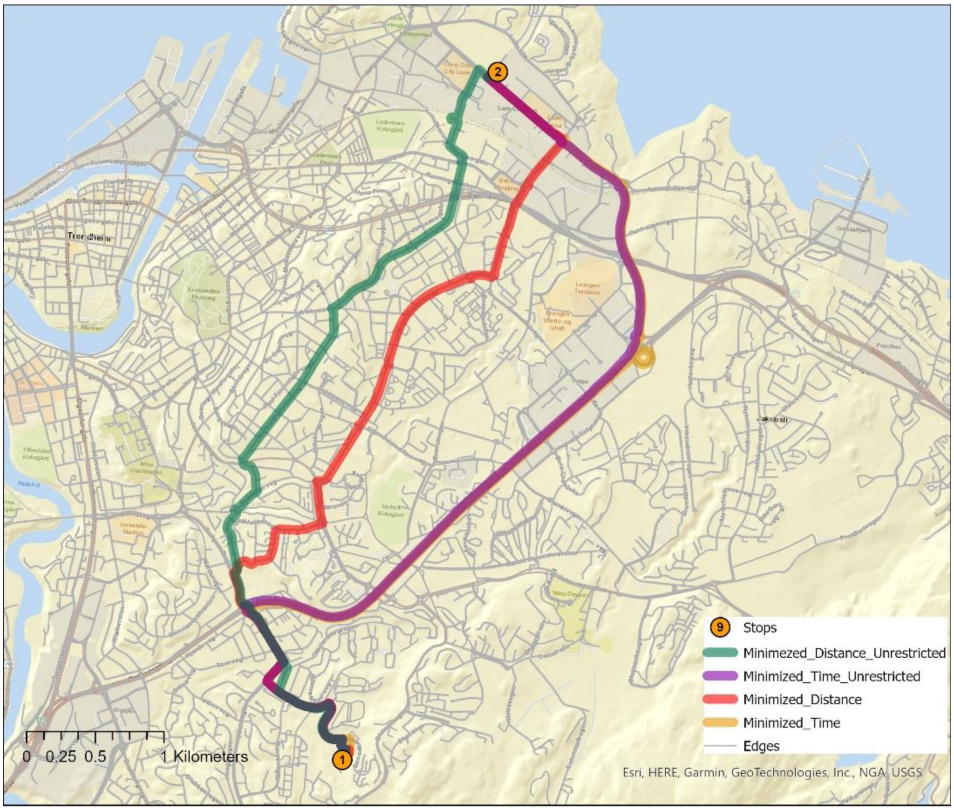


Fig. 2 Shortest and Fastest Routes with and without restrictions

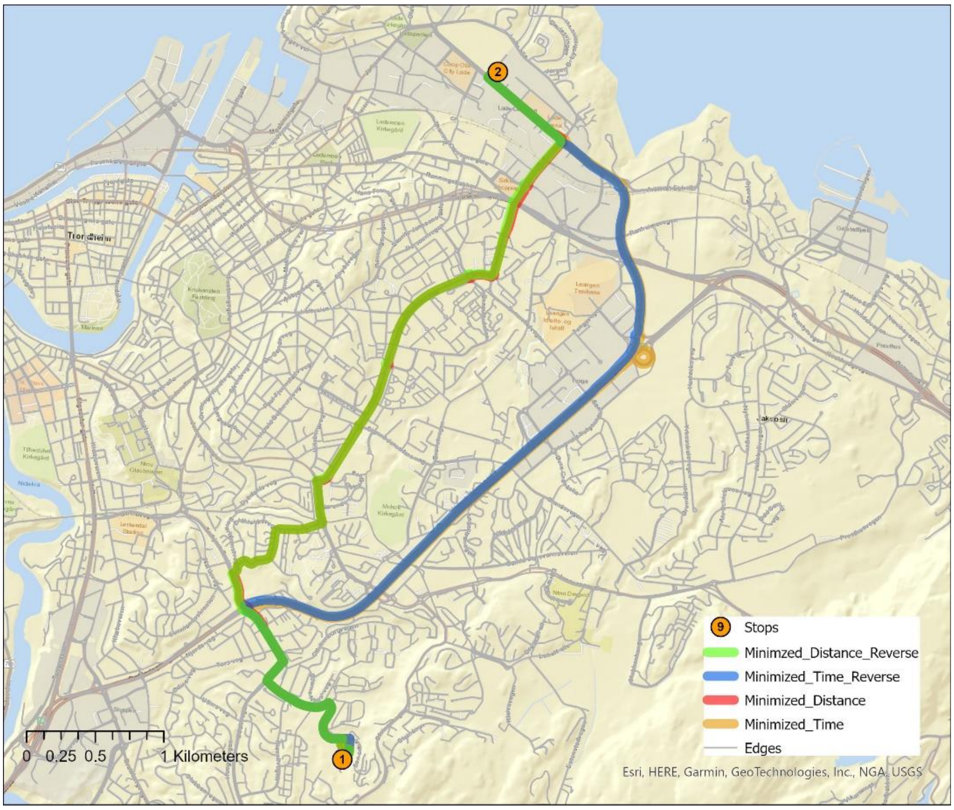


Fig. 3 Shortest and Fastest Routes in both directions

Shape	Name	FirstStopID	LastStopID	StopCount	Total_Minutes	Total_Length	Shape_Length
Polyline M	Minimized_Distance	3	4	2	12.55	7391.59	7393.32
Polyline M	Minimized_Time	3	4	2	9.97	8380.71	8382.64
Polyline M	Minimized_Distance_Unrestricted	3	4	2	14.72	6896.92	6898.55
Polyline M	Minimized_Time_Unrestricted	3	4	2	9.56	8001.08	8002.93
Polyline M	Minimized_Distance_Reversed	4	3	2	12.33	7368.89	7370.61
Polyline M	Minimized_Time_Reversed	4	3	2	9.66	8053.07	8054.93

When restrictions were removed a new shorter route was obtained while the fastest route stayed the same. When the sequence of stops was reversed, the function recommends the same route.

From the results it could be understood that there might be some car restricted roads in the city centre that leads to an alternate route calculation for shorter distance when all restrictions were removed. Also, there might not be one-way restrictions since the function recommends the same route in both directions.

2.1.3 For the fourth variation, some road barriers were added to the originally obtained shortest and fastest routes.

A point barrier was added to the E6 highway to block it to see what the next fastest route could be. Further, polygon barriers were added blocking Jonsvannsveien and Haakon VII's gate which were the first and last major roads in the shortest route.

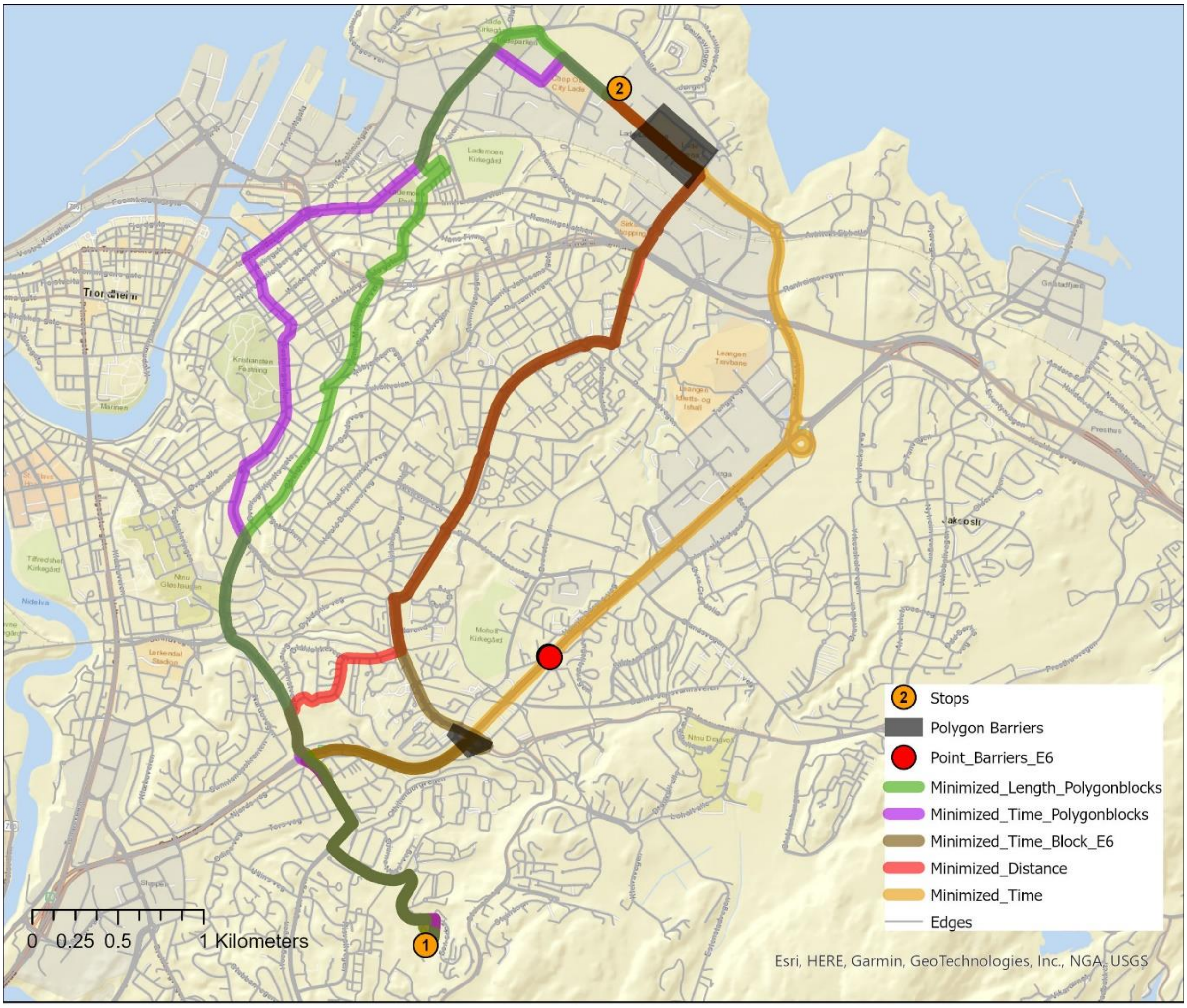


Fig 4. Shortest and Fastest Routes with added barriers

Shape	Name	FirstStopID	LastStopID	StopCount	Total_Minutes	Total_Length	Shape_Length
Polyline M	Minimized_Distance	3	4	2	12.55	7391.59	7393.32
Polyline M	Minimized_Time	3	4	2	9.97	8380.71	8382.64
Polyline M	Minimized_Time_Block_E6	3	4	2	11.99	8175.90	8177.81
Polyline M	Minimized_Time_Polygonblocks	3	4	2	14.15	8148.42	8150.36
Polyline M	Minimized_Lenght_Polygonblocks	3	4	2	14.73	7928.82	7930.70

From the map and the table, it could be observed that alternate optimal routes were calculated for the network when barriers were added to the shortest and fastest routes. These routes were slightly longer and slower than the most optimum ones.

2.2 Service Area Isochrone Function

This function creates a polygon defining the area in the network that can be reached in a given time or distance.

2.2.1 CitySyd was selected as the facility and its service area was calculated for cutoff intervals of 5,10,15 and more than 15 minutes.

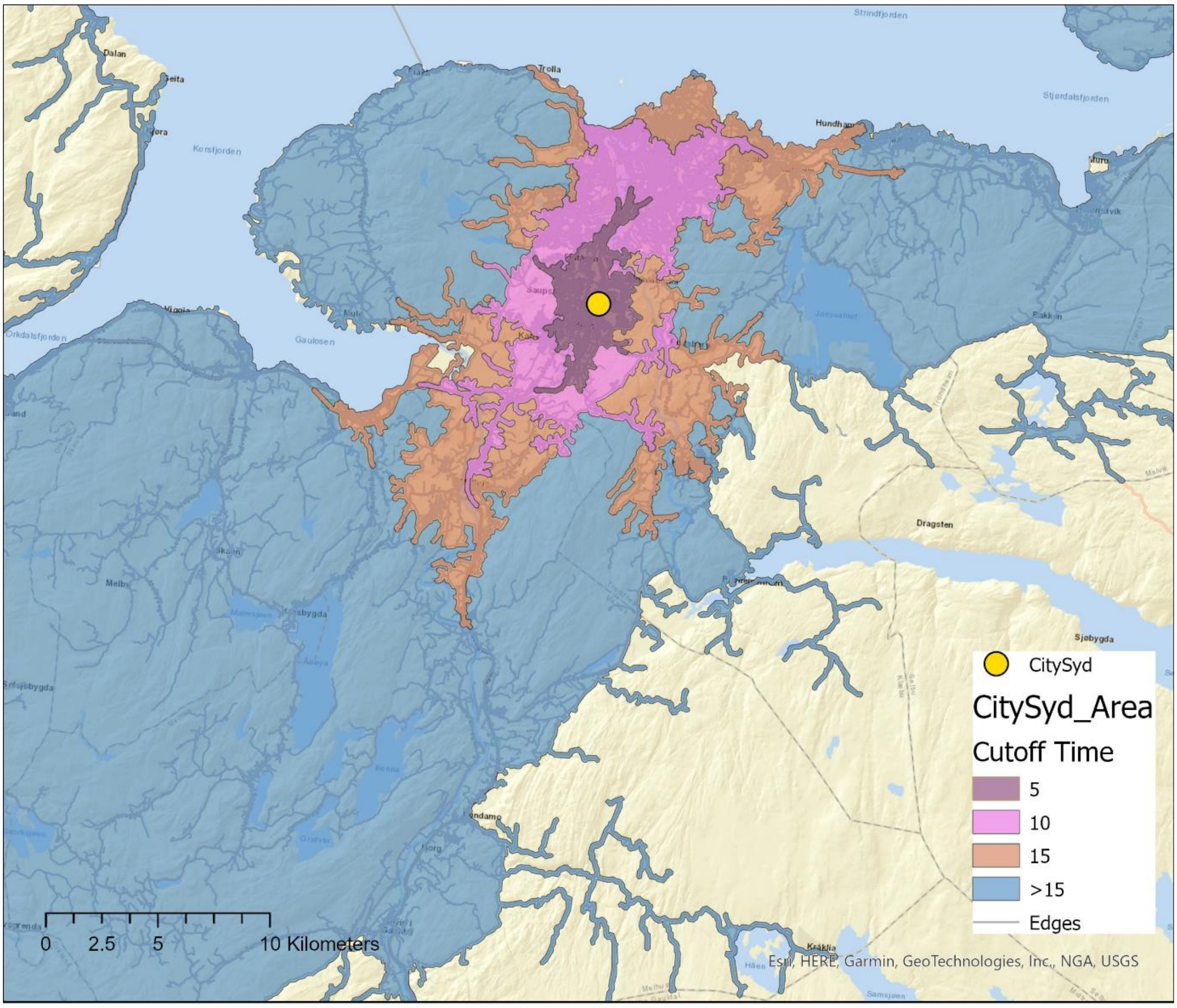


Fig 5. Service Area Isochrones - CitySyd

ObjectID	Shape	FacilityID	Name	FromBreak	ToBreak	Population	Shape_Area
1	Polygon	CitySyd	: 15 - 92	15	92	73207	1947837813
2	Polygon	CitySyd	: 10 - 15	10	15	66860	116053750
3	Polygon	CitySyd	: 5 - 10	5	10	104813	68850312.5
4	Polygon	CitySyd	: 0 - 5	0	5	36054	18821250

It was observed that the facility can be reached by all he population within 92 minutes. The maximum population could reach the location within 10 minutes. Some population points could not reach the facility which could be due to network error or no car route.

2.2.2 The analysis was now used to see how much population the three facilities of CitySyd, City Lade and Trondheim Torg could cover with a cutoff time of 15 minutes.

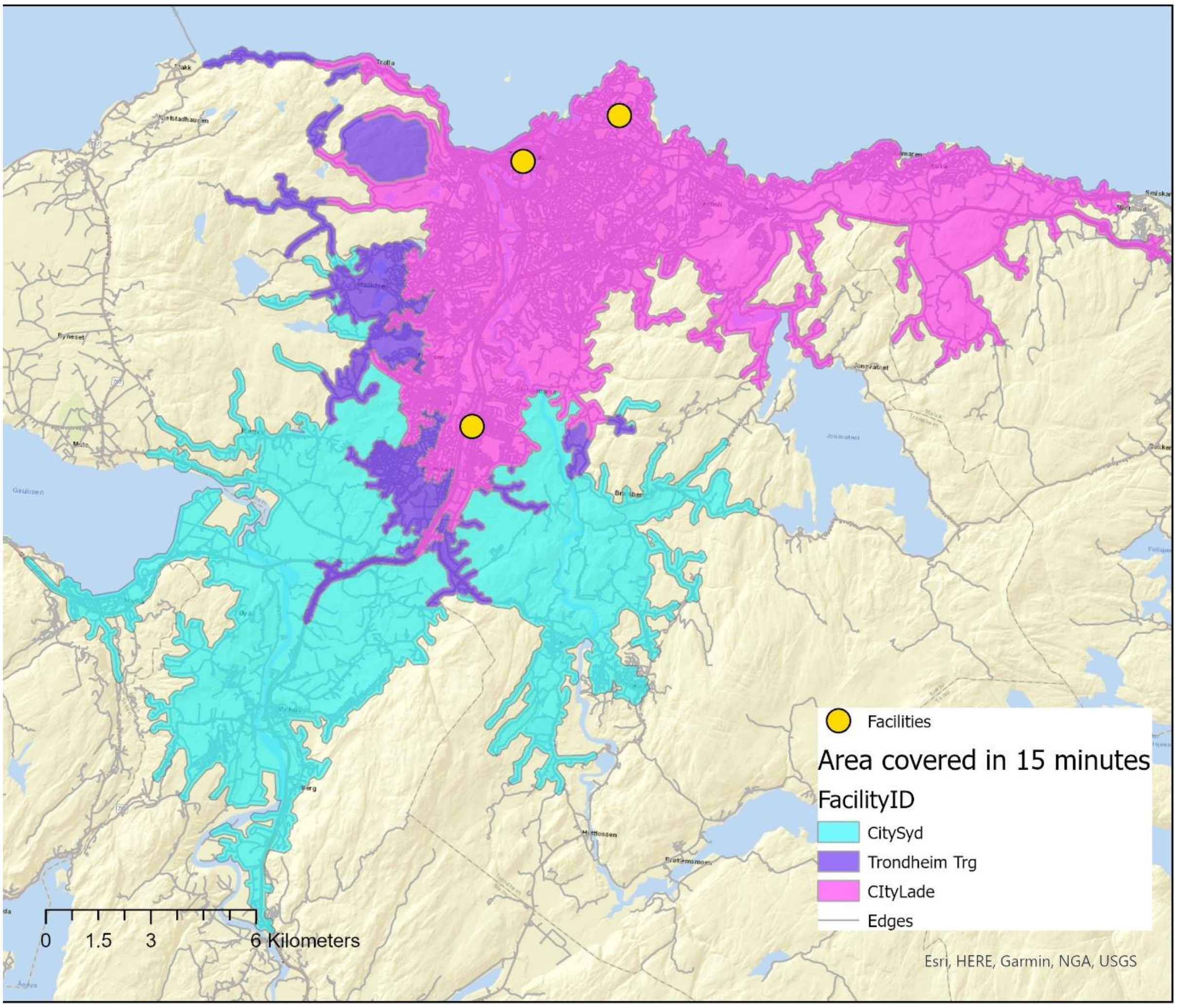


Fig 6. Service Area Isochrones for three facilities

ObjectID	Shape	FacilityID	Name	FromBreak	ToBreak	Population	Shape_Area
1	Polygon	CitySyd	: 0 - 15	0	15	207741	203749063
2	Polygon	Trondheim Torg	: 0 - 15	0	15	193265	115488438
3	Polygon	CityLade	: 0 - 15	0	15	176394	108178125

CitySyd covers the maximum area as well as maximum population. Although all three facilitates cater to a similar number of populations. Also, these population and area numbers are overlapped, and not distributed amongst facilities.

2.3 Closest Facility Function

This function connects destination points to their closest facility based on time or distance.

2.3.1 For this exercise, the following six spots were initially selected as the Post Office facilities and routes were calculated for all the population grid points. 6878 Routes were obtained for 6907 population grid points. This could be due to error in network model or if no route would have been available.

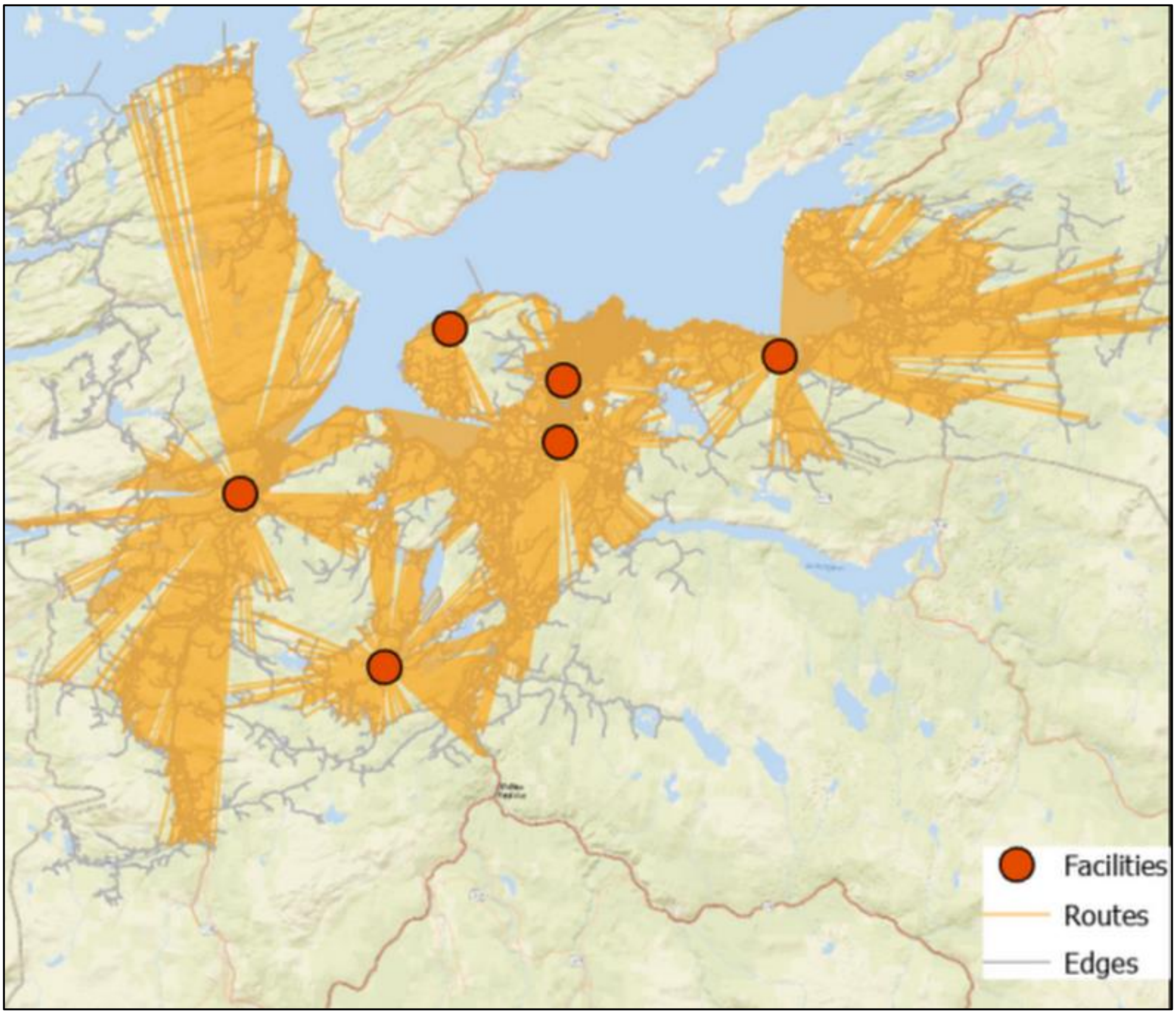


Fig 7. Routes allocated to Population Points to the Closest Facility

FacilityID	Shape	Name	Frequency	SUM_Population	MEAN_Total_Minutes	MEAN_Total_Length
1	Point	Kråkdalsvegen	1565	18828	23.46	23584.77
2	Point	Bosbergvegen	299	3180	7.00	5859.70
3	Point	Hølondvegen	551	4392	16.37	14600.51
4	Point	Forsøkslia	1096	167022	8.05	6400.24
5	Point	Torgardsvegen	1553	42584	12.84	13004.10
6	Point	Stavsjøvegen	1814	45744	17.85	19362.03

It was observed that the post office within the city centre (Forsøkslia) serves the most people and has the least mean time. The post offices outside the main city have the longest mean time. One post office serves very few people. Some adjustments to the selected post office locations could be made to get better locations.

2.3.2 For the second variation, few more possible post office locations were added, while the cut off time to travel was selected as 15 minutes.

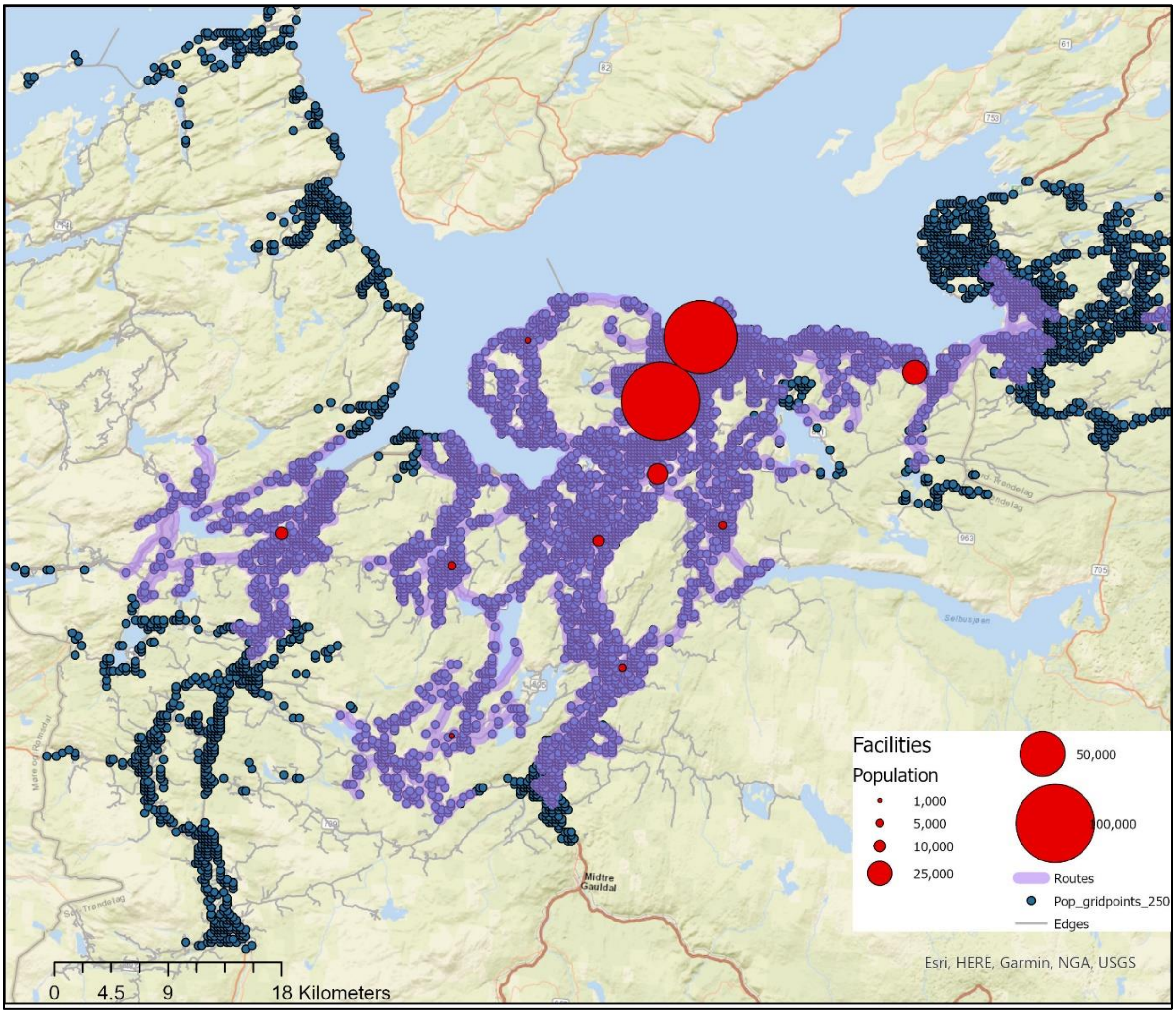


Fig 8. Post Office facilities based on the population they cater

FacilityID	Shape	Name	FREQUENCY	SUM_Population	MEAN_Total_Minutes	MEAN_Total_Length
1	Point	Skaunavegen	395	5033	7.57	6533.57
2	Point	Melhus	391	9430	5.56	4697.58
3	Point	Rosenborg gate	480	83894	6.93	5186.58
4	Point	Hesteskoen	293	5498	7.44	6175.70
5	Point	Sørkringvegen	127	592	9.00	9160.48
6	Point	Langlandsvegen	411	4570	8.10	7543.58
7	Point	Kråkdalsvegen	514	10878	8.94	8715.30
8	Point	Bosbergvegen	299	3180	7.00	5859.70
9	Point	Hølondvegen	247	1707	8.69	7758.03
10	Point	Forsøkslia	681	90382	6.72	4872.25
11	Point	Torgardsvegen	375	20621	6.58	5943.82
12	Point	Stavsjøvegen	566	25012	9.56	10133.02

From the map and the graph, following information could be inferred – The post offices within the city centre serve the most people. With a cut-off of 15 mins, a few places far apart from the main city could not be served. Around 4779 population grid points could be served out of 6907.

2.4 OD Cost Matrix

OD cost matrix calculates the optimum route between multiple start and end points and gives us results for all possible combinations.

2.4.1 Minimizing the time for whole population (optimization principle)

40 locations around the Trondheim municipality and neighbouring municipalities were selected to find the best location for a health institution and were treated as origins in the analysis. The population grid points were considered as the destinations.

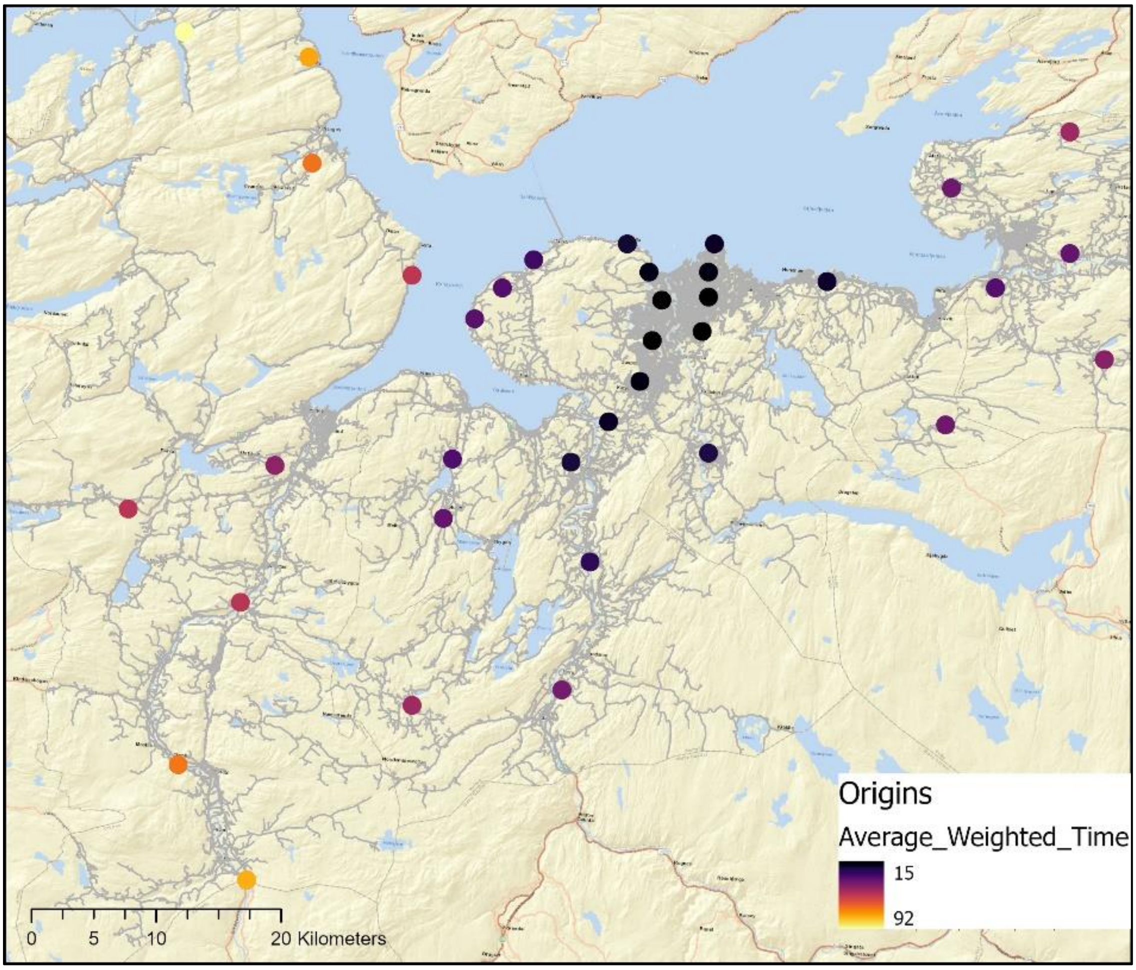


Fig 9. Possible Locations for a Health Institution based on Time

OriginID	FREQUENCY	MEAN_Total_Minutes	MAX_Total_Minutes	SUM_Weighted_Time	SUM_Pop	Avg_Weighted_Time
3	6878	31.376549	97.865662	4321845	281750	15
22	6878	30.62575	94.846183	4323685	281750	15
4	6878	32.271318	97.432631	4580887	281750	16
23	6878	32.19803	98.836702	4626435	281750	16
2	6878	33.388008	101.468043	4683185	281750	17
10	6878	30.699373	92.107383	4851428	281750	17
5	6878	34.891132	101.031063	5170967	281750	18

Seven possible locations for the health institution were selected based on the average time taken by the whole population to reach the location, along with the maximum time taken by people to reach the location.

2.4.2 Minimizing distance for whole population (Justice principle)

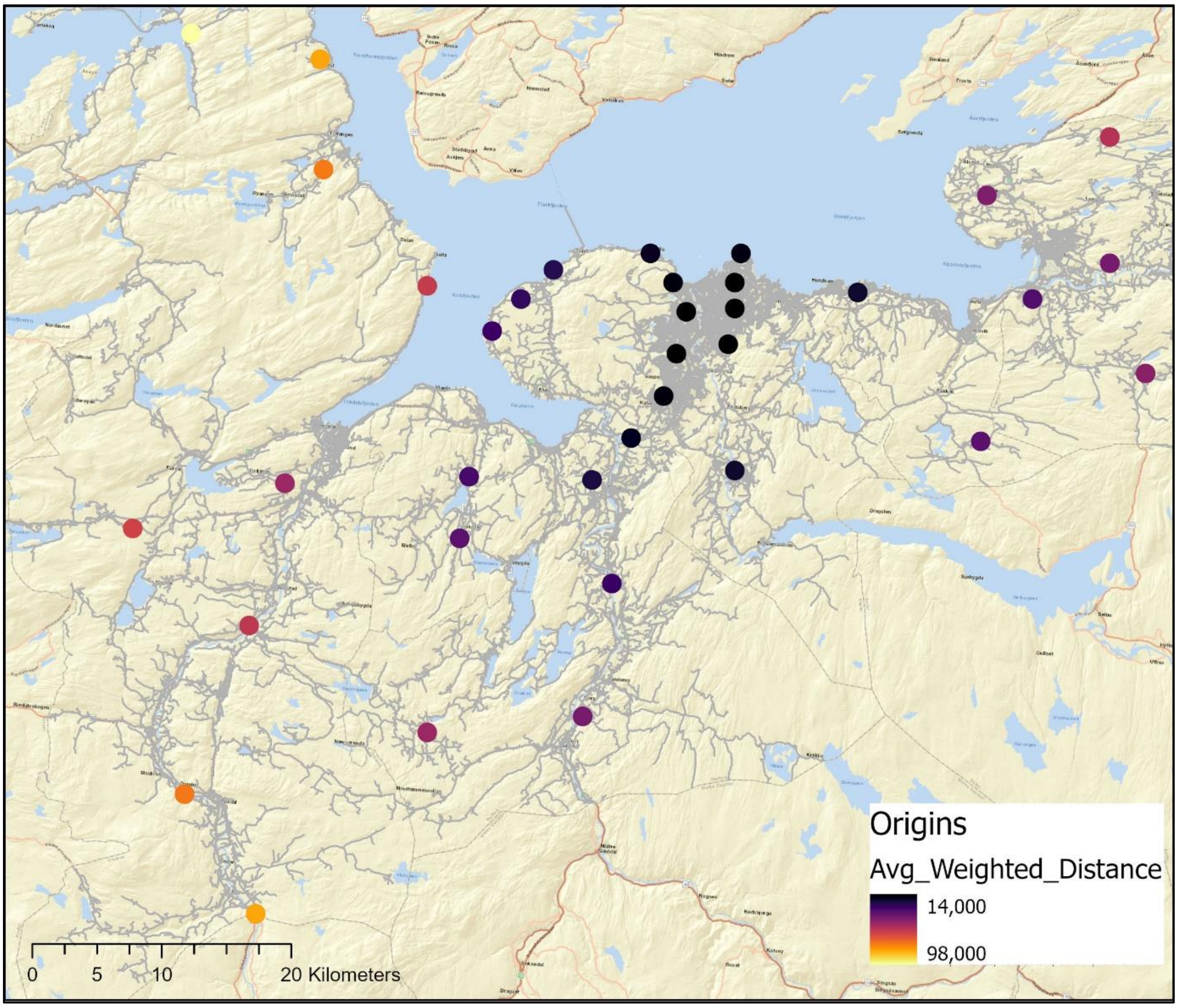


Fig 10. Possible Locations for a Health Institution based on Distance

OriginID	FREQUENCY	MEAN_Total_Length	MAX_Total_Length	SUM_Weighted_Distar	SUM_Pop	Avg_Weighted_Distan
22	6878	31030.43	97396.97	4013783146	281750	14246
3	6878	32888.60	103843.56	4065710371	281750	14430
23	6878	32461.40	103013.47	4110236772	281750	14588
2	6878	33620.14	105225.12	4168109763	281750	14794
4	6878	33133.74	101420.61	4237848751	281750	15041
10	6878	30495.68	93823.07	4477570331	281750	15892
5	6878	34347.69	103479.02	4494838331	281750	15953

Similarly, seven locations were selected based on the average weighted distance and the maximum distance from the location.

It could be observed that the seven points selected from both the minimizations are the same, which are the most optimum locations to place the institution.

EXERCISE 2

Network Construction and Editing

Speed Models

Exercise 2: Network Construction and editing Speed Models

1. Tools and Data Used -

1.1. Database –

a) Bike_links

b) Elevation data (dtm.tif)

1.2. Tools –

a) Basic ArcGIS tools (Creating, Modifying and Exporting Feature Classes, Layout, Symbology)

b) Basic Database Management tools (Creating Fields, Summarizing Data)

c) Network Analysis functions (Route, Service Area)

d) Sykkelhastighet Add-In (ATP Model for bicycle speed)

1.3. Units –

a) Distance - Meters

b) Time - Minutes

2. Results

2.1. Creating a basic network

2.1.1 Using the basic create line feature, links for the network are created in a feature data set with elevation. Attributes like one-way restriction, speed and minutes are added in the network's attribute table.

Table 1: Attribute table for the digitized network

OBJECTID	SHAPE *	Shape_Length	OneWay	Speed	Minutes
4	Polyline Z	130.044583	<Null>	50	0.156054
5	Polyline Z	55.695383	<Null>	50	0.066834
6	Polyline Z	61.007428	TF	50	0.073209
7	Polyline Z	225.992208	N	50	0.271191
8	Polyline Z	106.372143	<Null>	50	0.127647
9	Polyline Z	68.515741	<Null>	30	0.137032
10	Polyline Z	153.650724	<Null>	30	0.307302
11	Polyline Z	261.48419	<Null>	30	0.522968

Finally, the network is built using the network data, and service area analysis is run to check the model with length as impedance.

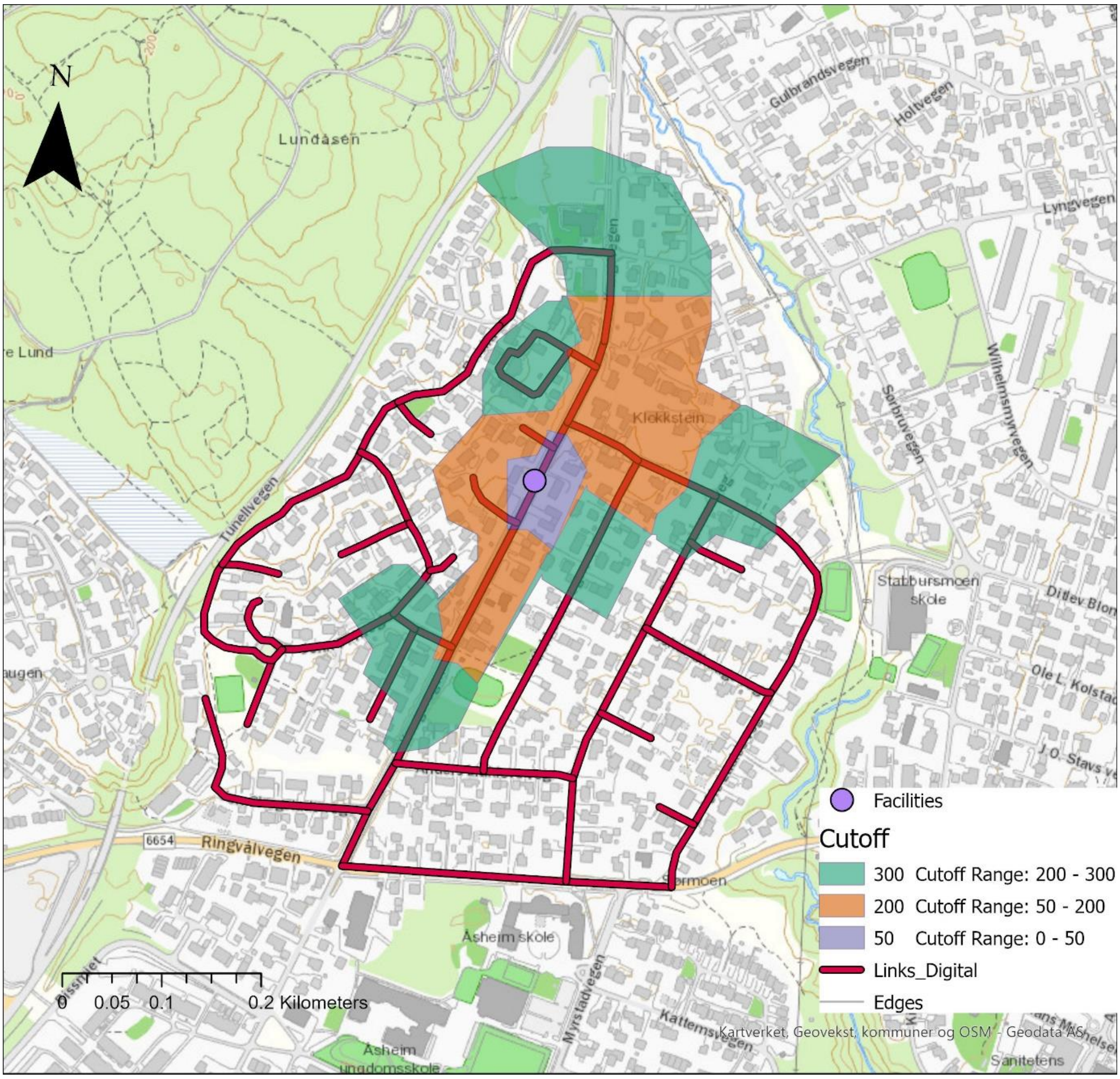


Fig. 1 Digitised Network with Closest Facility Analysis

2.1.2 For the second variation, a travel time cost is added to the created network. A new travel attribute for time cost is added by using the [MINUTES] attribute created in 2.1.1. We then run the route analysis with first length and then time as the impedance.

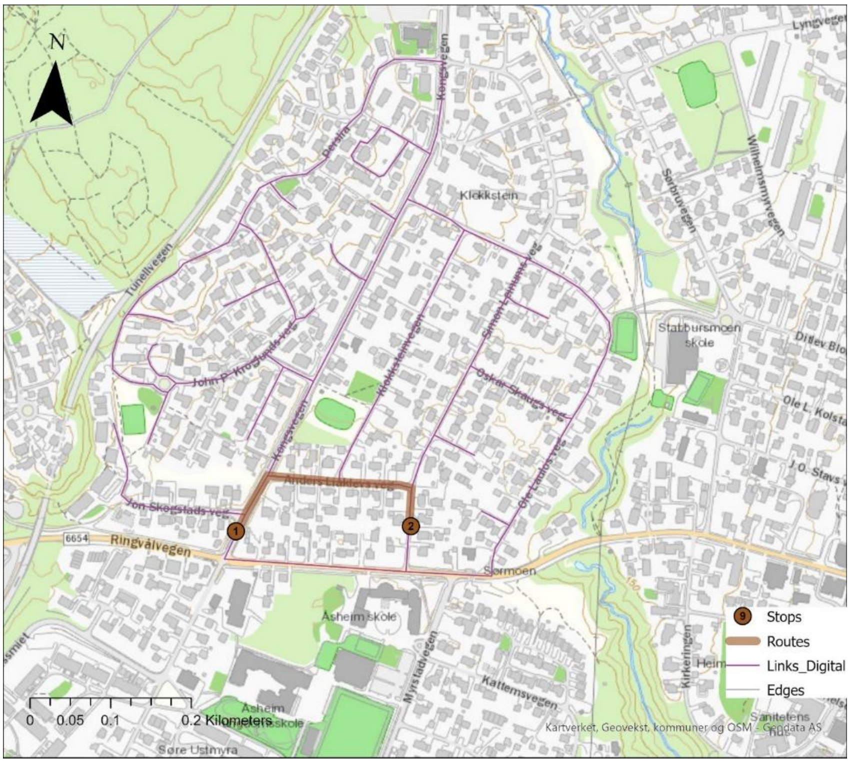


Fig. 2 Route Analysis for the network with length as impedance

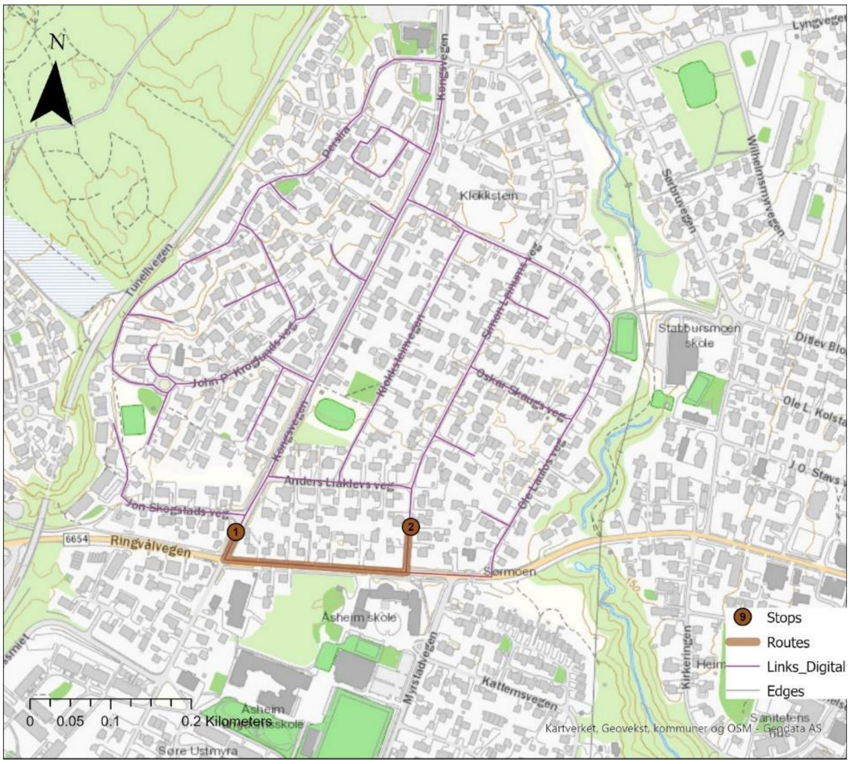


Fig. 3 Route Analysis for the network with time as impedance

We observe the route analysis shows different route for different impedance as the route in Fig 3 has a speed of 50 and takes lesser time compared to the route in Fig 2.

2.1.3 For the third variation, a restriction variable is added to the created network

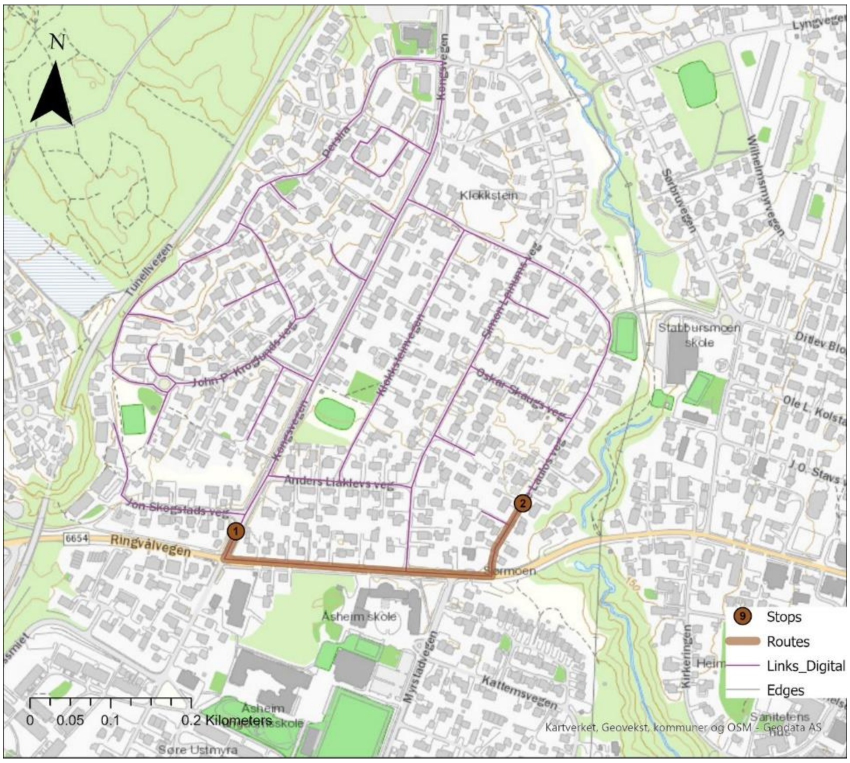


Fig. 4 Route Analysis for the network without restrictions

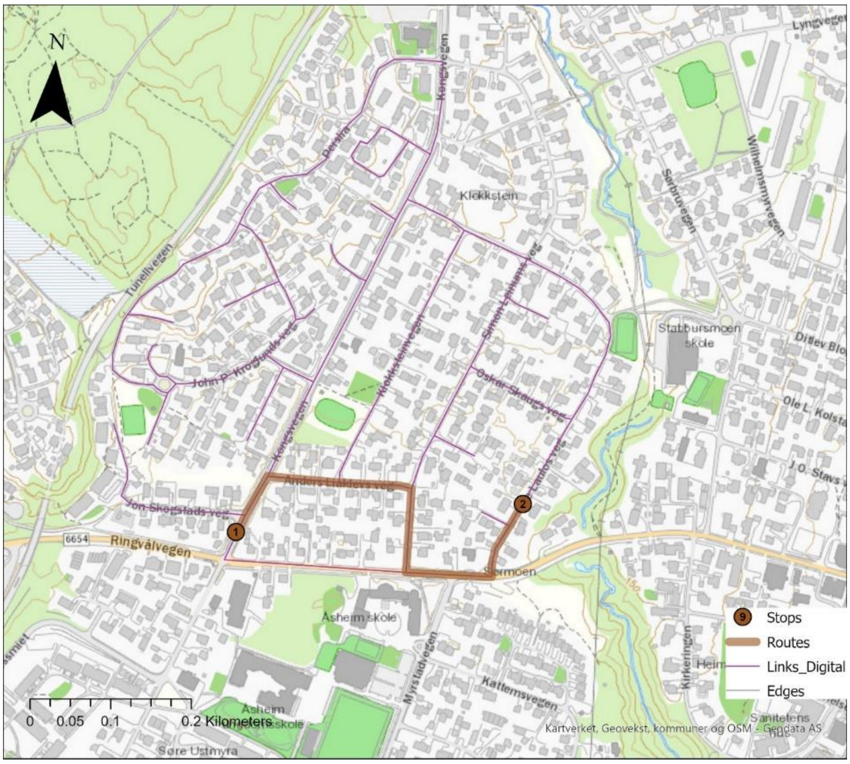


Fig. 5 Route Analysis for the network with restrictions

The route in Fig 5 takes a longer distance as the route in Fig 4 has been restricted.

2.2 Creating a Bicycle network

The bicycle speeds and Minutes have been calculated using the ATP Model (Sykkelhastighet Add-In).

Tunnels and motor highways in the network were prohibited for bicycle movement.

Travel attributes were added, and the network was built.

Service Area analysis for cut-offs 5,10 and 20 minutes was run on the network.

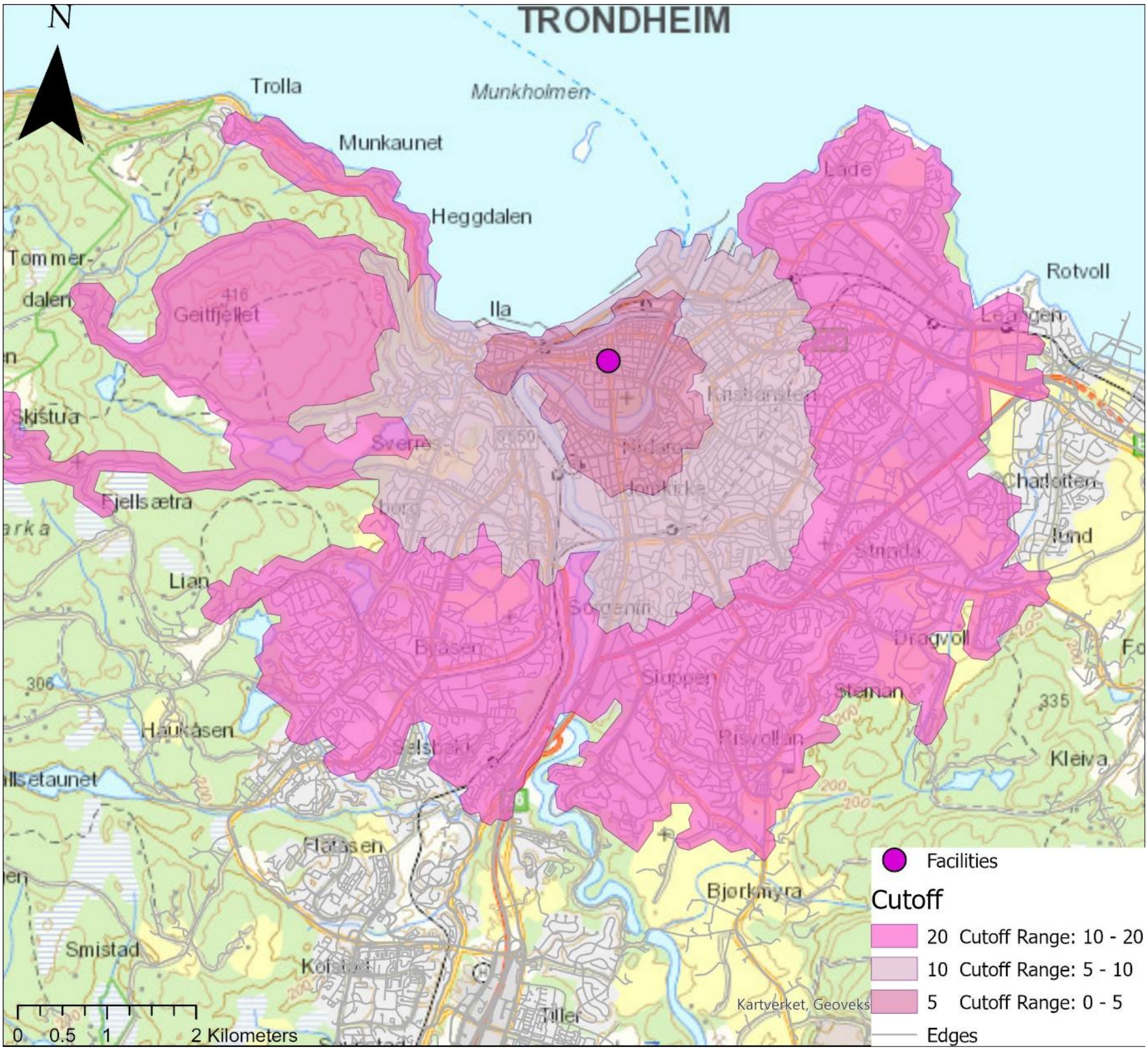


Fig. 6 Service area analysis for the bicycle network with time as impedance and restrictions turned on

2.3 Creating a Pedestrian Network

Tobler's hiking speed formula is used to calculate the pedestrian speeds. The new speeds were used to calculate the minutes.

Tunnels and motor highways in the network were prohibited for pedestrian movement.

Travel attributes were added, and the network was built.

Service Area analysis for cut-offs 5,10 and 20 minutes was run on the network.

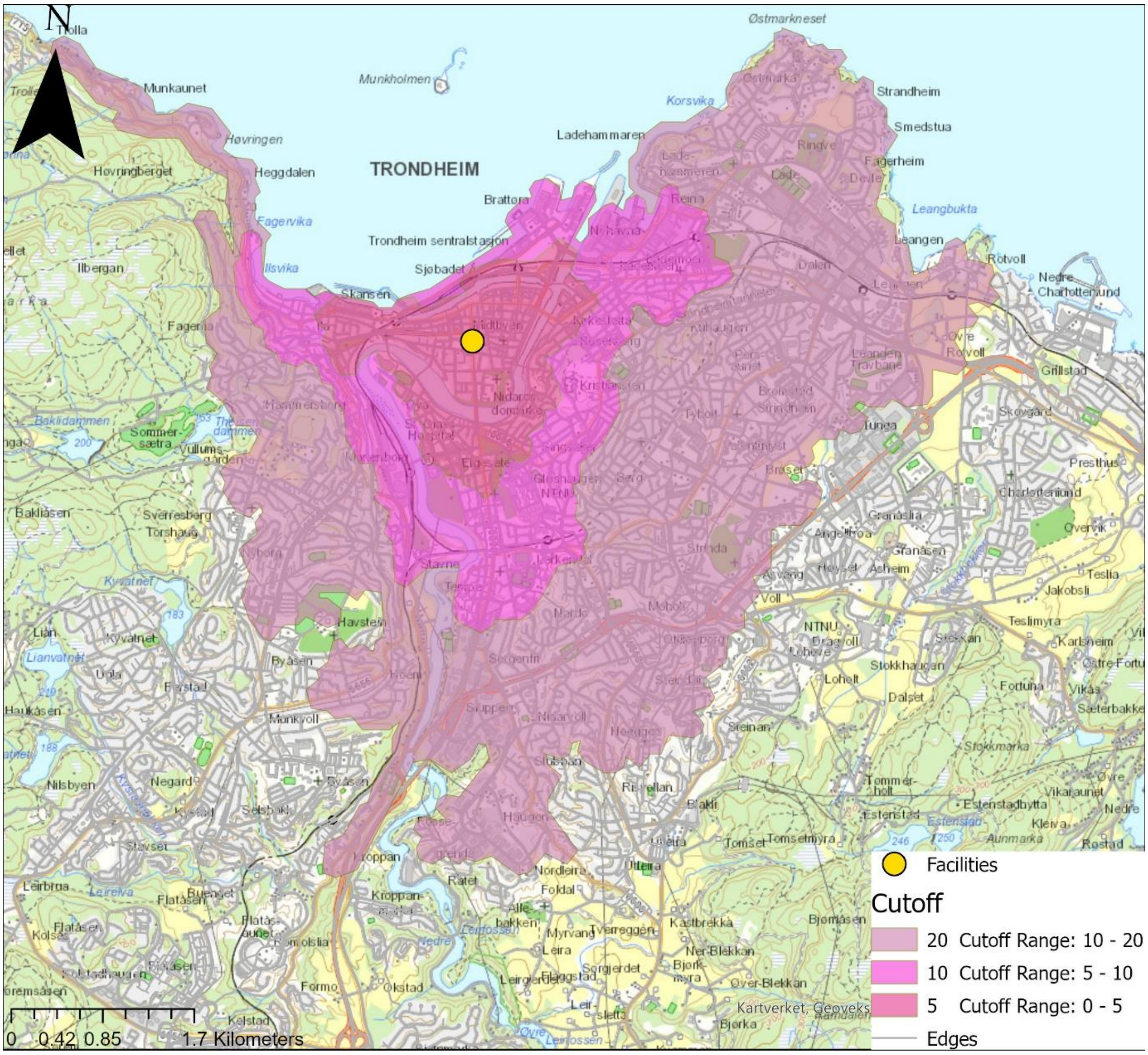


Fig. 7 Service Area Analysis for the pedestrian network with time as impedance and restrictions

Both bicycle and pedestrian networks were successfully built, and service area analysis was run on the network. Fig 6 and Fig 7 show different areas the facility can serve with bicycle and pedestrian movement respectively.

EXERCISE 3

Constructing a Transit Network

Exercise 3: Constructing a transit network

1. Tools and Data Used -

1.1. Database –

a) Bike Links

b) XML Template

c) Point feature classes as grocery store locations

d) Point feature classes as employee locations

1.2. Tools –

a) Basic ArcGIS tools (Creating, Modifying and Exporting Feature Classes, Layout, Symbology)

b) GTFS to Public Transit Data Model function

c) Network Analysis functions (Route, Service Area, Closest Facility, OD Cost Matrix)

1.3. Units –

a) Distance - Meters

b) Time - Minutes

2. Results

2.1. Construction of Public Transit Network

A schedule aware public transit network was constructed using bicycle network as a base and by using the GTFS Data and ESRI template.

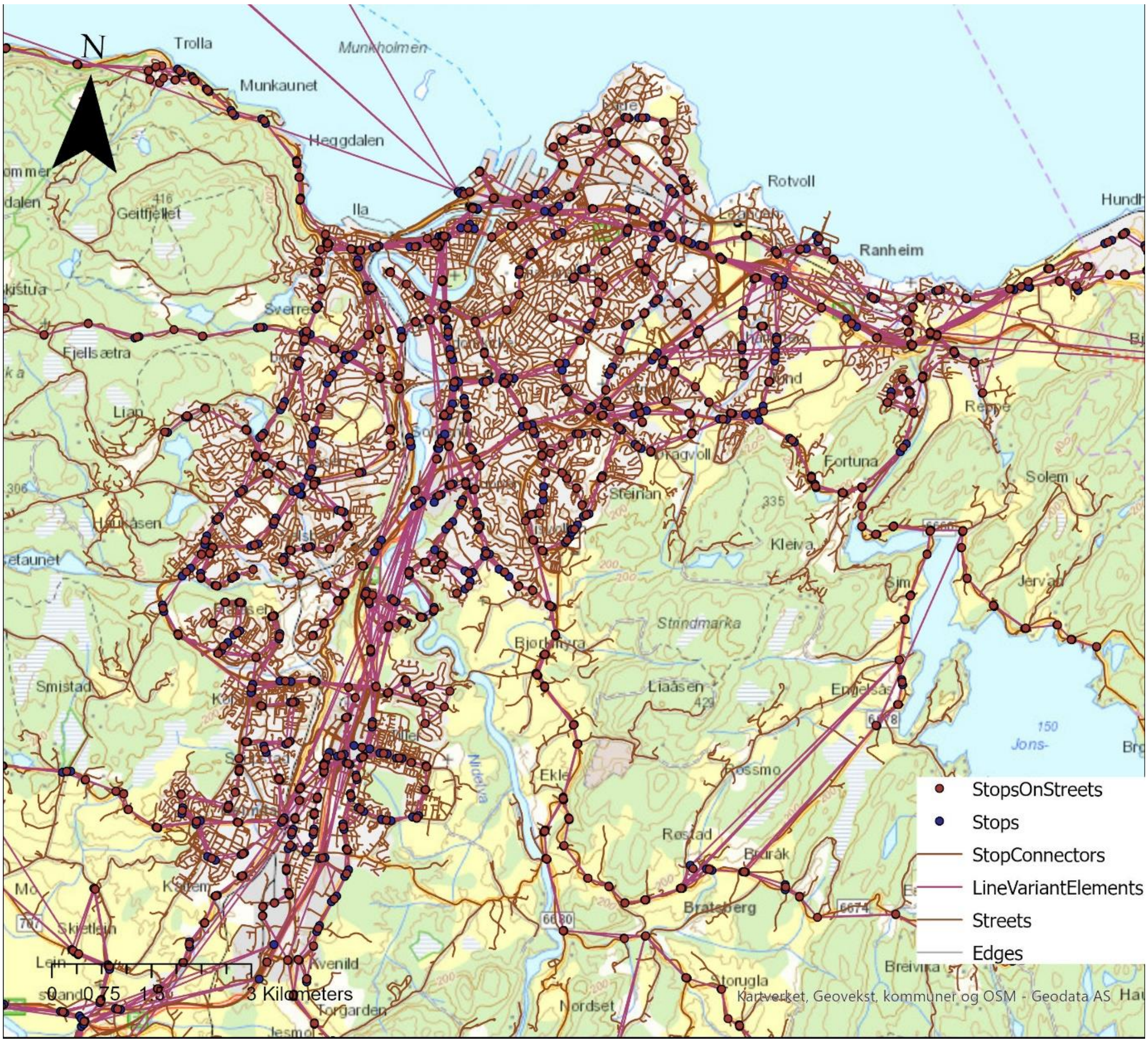


Fig 1. Schedule aware Public Transit Network

2.2 Travel Time to city center by two different starting times

3 stops were selected in Steinan, Heimdal and Ranheim

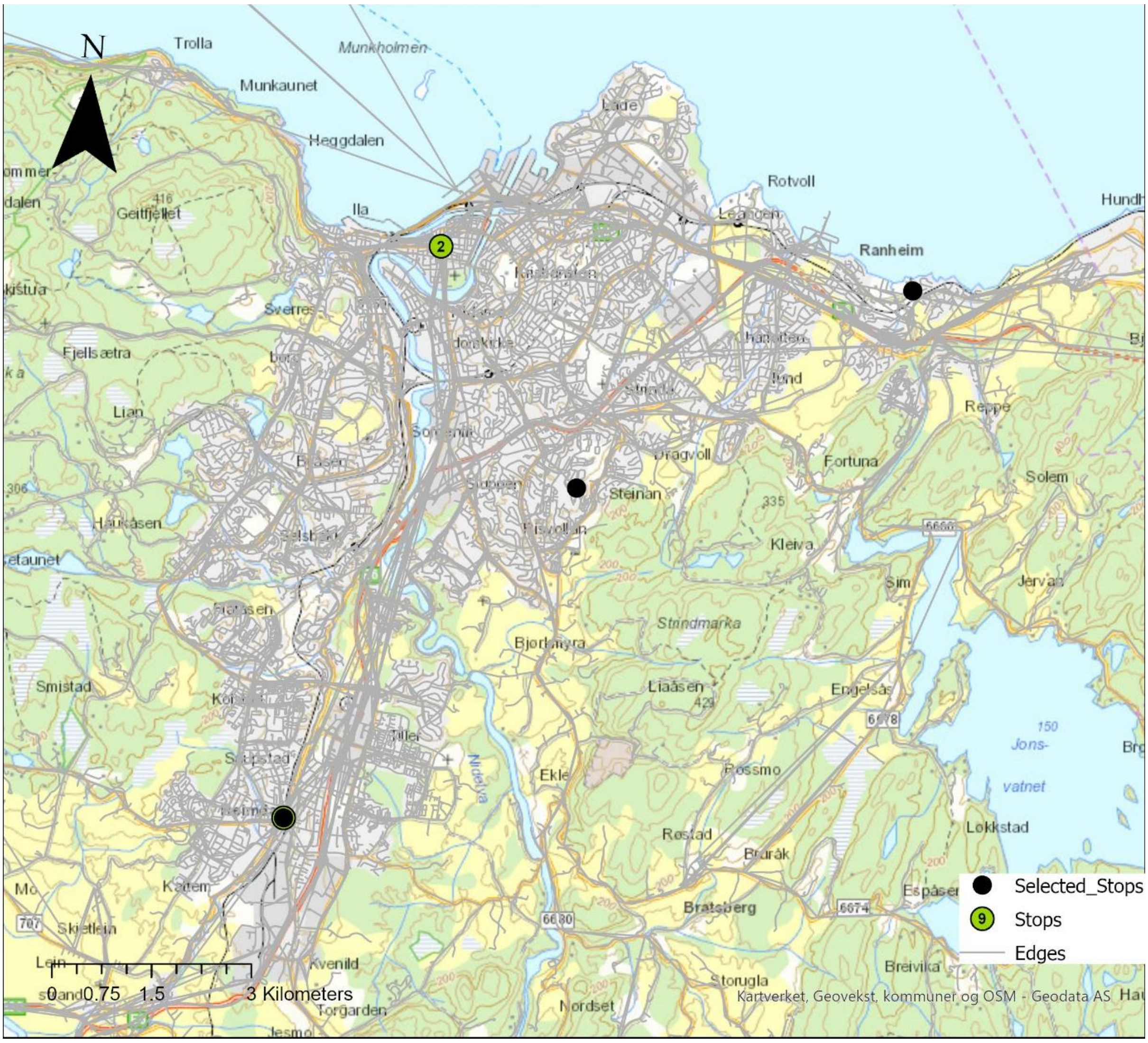


Fig.2 Selected Stops

Routes were calculated for 12PM and 9PM for a weekday.

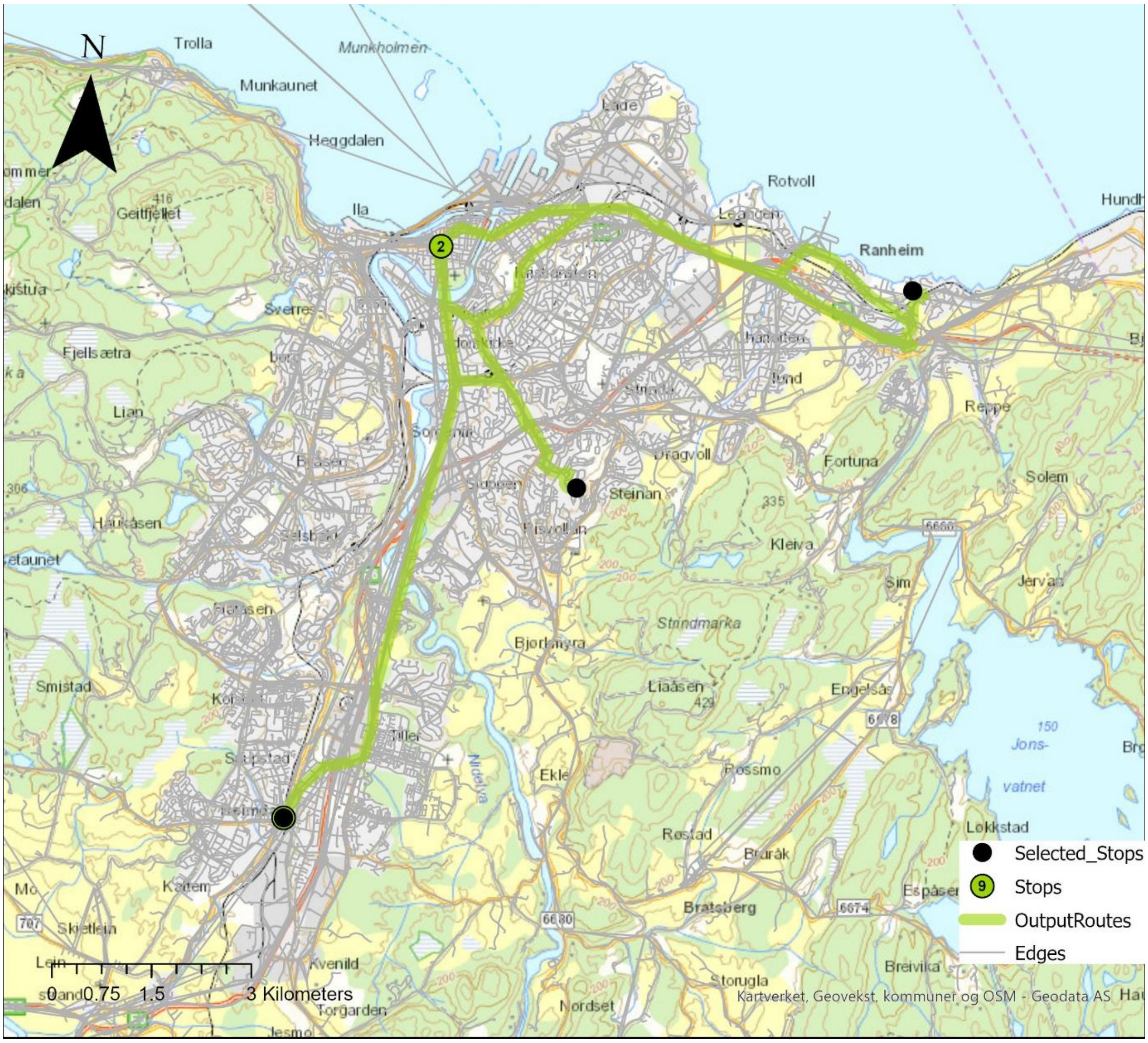


Fig 3. Routes from selected stop to city center using public transport network

OBJECTID	Name	FirstStopID	LastStopID	StopCount	StartTime	EndTime	Total_PublicTransitTin	Total_WalkTime
3	Ranheim - CityCenter	5	1	2	09-01-1990 12:00	09-01-1990 12:31	31.642551	9.567235
4	Ranheim - CityCenter (21)	5	1	2	09-01-1990 21:00	09-01-1990 21:39	39.642551	14.830909
5	Steinan - CityCenter	7	1	2	09-01-1990 12:00	09-01-1990 12:33	33.642551	22.446697
6	Steinan - CityCenter (21)	7	1	2	09-01-1990 21:00	09-01-1990 21:27	27.661143	14.553368
8	Heimdal - CityCenter	8	1	2	09-01-1990 12:00	09-01-1990 12:24	24.642551	0.642551
7	Heimdal - CityCenter (21)	8	1	2	09-01-1990 21:00	09-01-1990 21:24	24.642551	0.642551

We see from the table that there is more walking/waiting time for Ranheim and Steinan than for Heimdal which is because the bus frequency is more in Heimdal. For Steinan, waiting/waiting time is more for 12PM than for 9PM.

2.3 Number of employees that can be reached in 30 minutes

We use service area analysis towards the facility and Spatial join feature on the public transit network.

We check for two different times, one in the morning (0900) and the other at (1600).

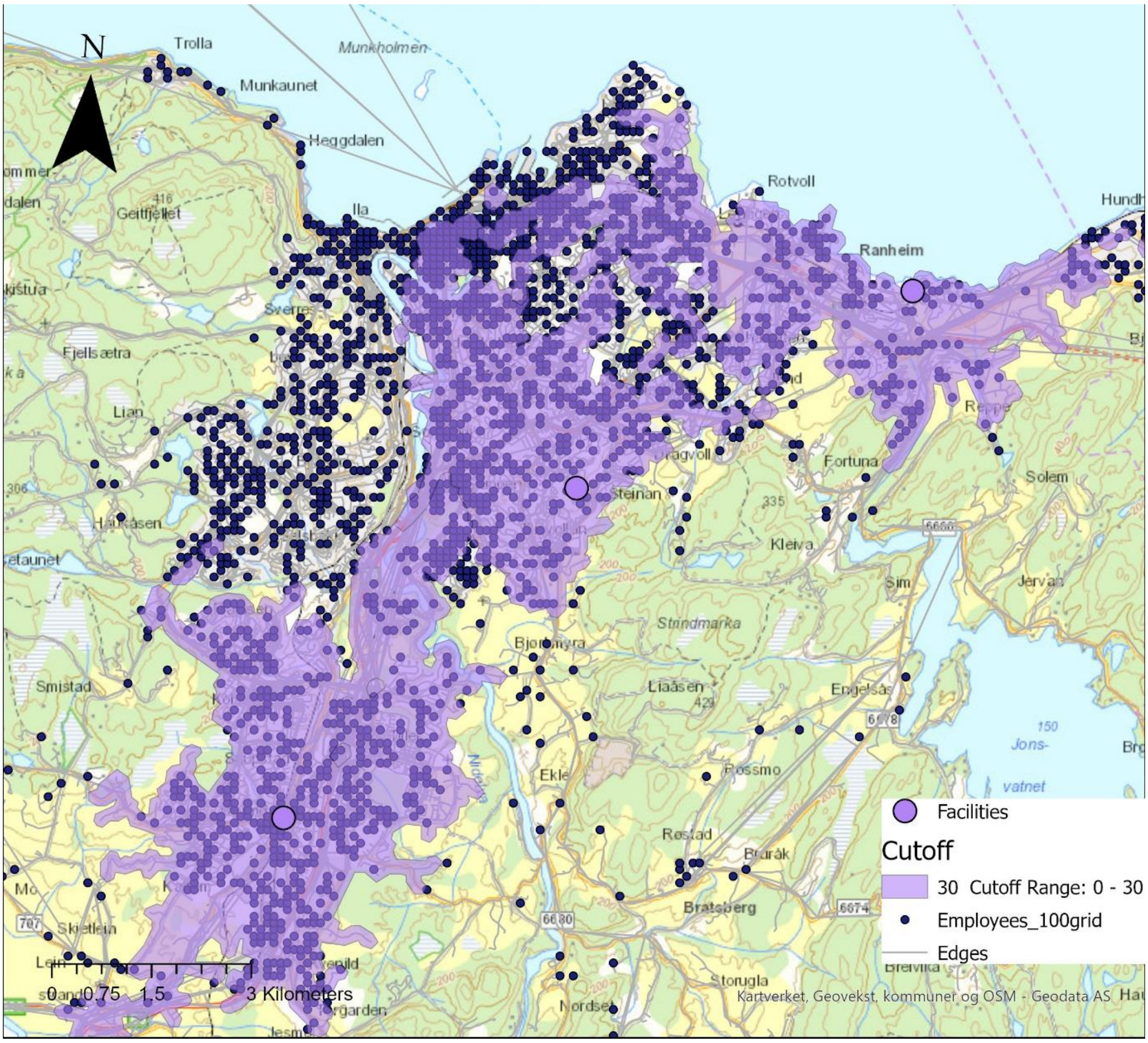


Fig 4. Number of employees that can be reached in 30 minutes

FacilityID	Name	ansatte	Shape_Area
3	Heimdal : 0 - 30	68048	36339062.5
2	Steinan : 0 - 30	52280	14567500
1	Ranheim : 0 - 30	42421	16930625
3	Heimdal : 0 - 30 (16)	69230	33475000
2	Steinan : 0 - 30 (16)	51983	14429062.5
1	Ranheim : 0 - 30 (16)	20563	16118125

2.4 Minimum Trave time for grocery stores at 13:00

We use the closest facility function for the stops and grocery stores at 13:00 on a weekday.

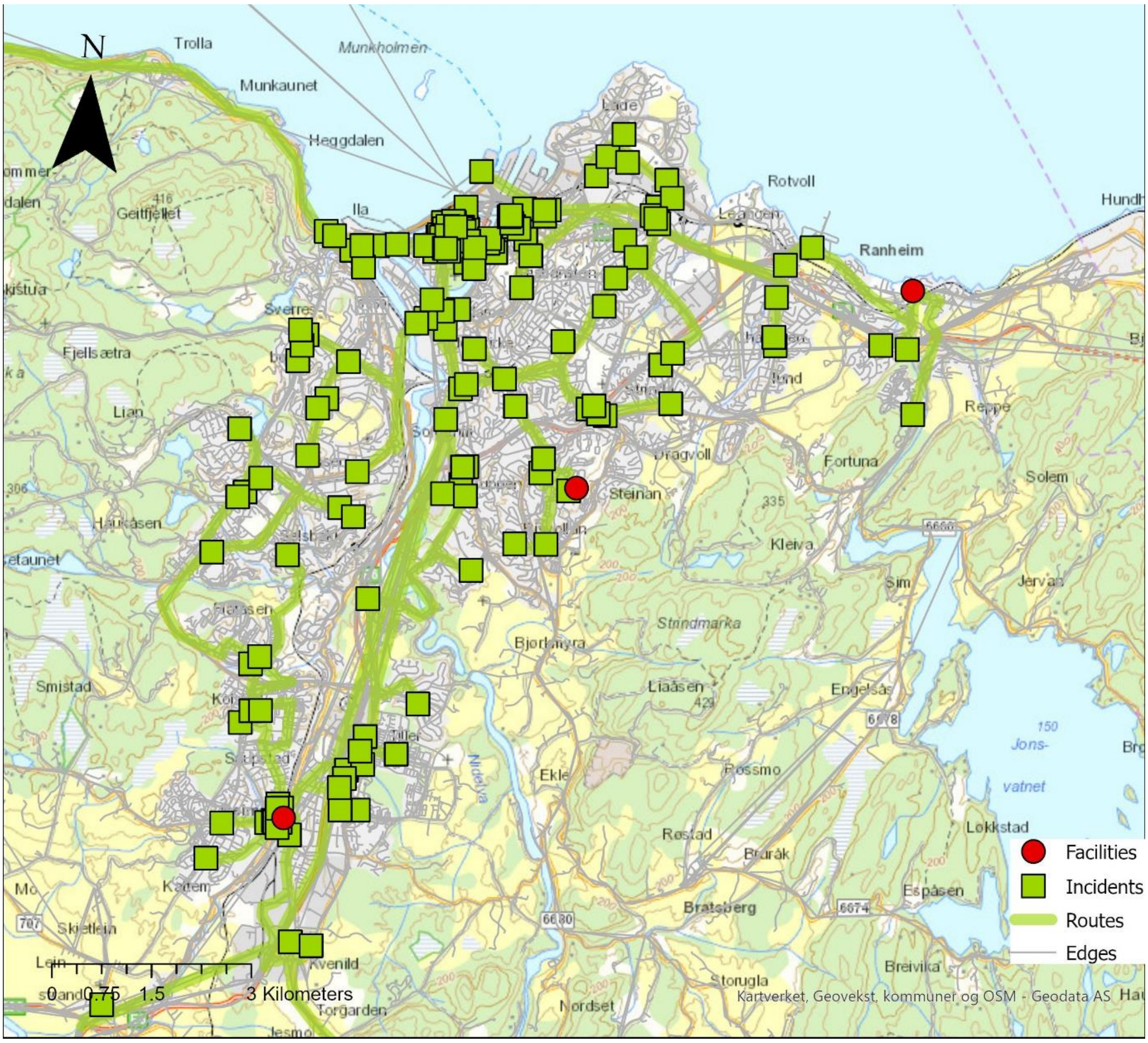


Fig 5. Routes from selected stop to grocery stores with a PT network

ObjectID	Name	FacilityID	FacilityRank	StartTime	EndTime	Total_PublicTransitTin	Total_WalkTime
84	Heimdal - Location 84	3	1	11-01-1990 13:00	11-01-1990 13:01	1.140822	1.140822
94	Steinan - Location 94	2	1	11-01-1990 13:00	11-01-1990 13:01	1.317332	1.317332
95	Ranheim - Location 95	1	1	11-01-1990 13:00	11-01-1990 13:15	15.901084	15.901084
40	Heimdal - Location 40	3	1	11-01-1990 13:00	11-01-1990 13:05	5	0
88	Steinan - Location 88	2	1	11-01-1990 13:00	11-01-1990 13:12	12.861687	12.861687
7	Heimdal - Location 7	3	1	11-01-1990 13:00	11-01-1990 13:15	15.03672	8.03672

We show some selected routes in the table to observe that access to grocery stores in the selected stop at Ranheim is far while there are multiple grocery stores available around Heimdal, and a few are available at Steinan.

EXERCISE 4

Accessibility mapping

Making an ABC Map

Exercise 4: Accessibility Mapping
Making an ABC Map

1. Tools and Data Used -

1.1. Database –

a) Car Network, PT Network, Pedestrian Network, Biking Network

b) Population data as grid points

c) Gridpoints_500 for Trondheim

1.2. Tools –

a) Basic ArcGIS tools (Creating, Modifying and Exporting Feature Classes, Layout, Symbology)

b) Basic Database Management tools (Spatial Join, Join, Creating Fields, Summarizing Data)

c) Network Analysis functions (Closest Facility, OD Cost Matrix)

1.3. Units –

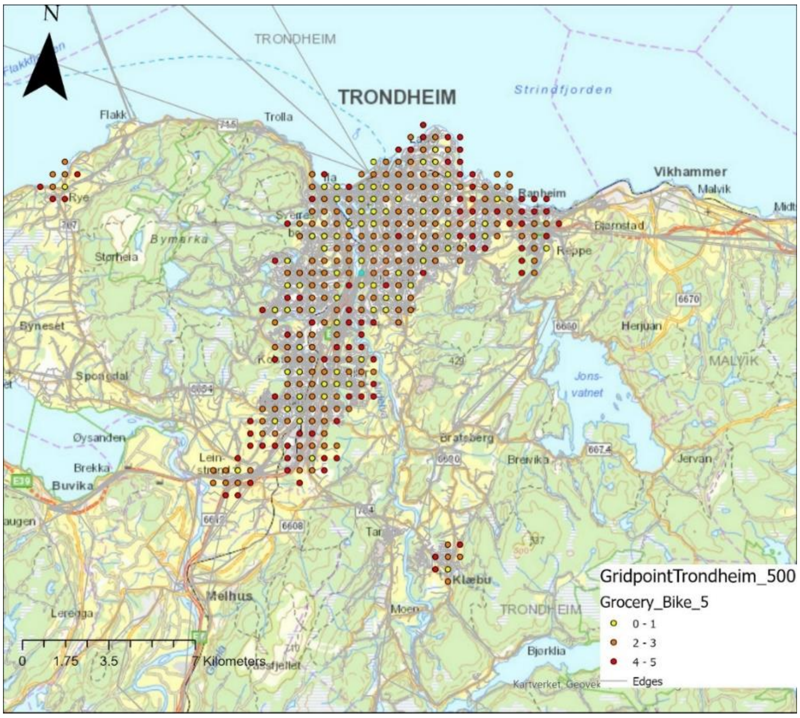
a) Distance - Meters

b) Time - Minutes

Grindpoint_500 was used for this exercise for the municipalities of Trondheim and Klæbu.

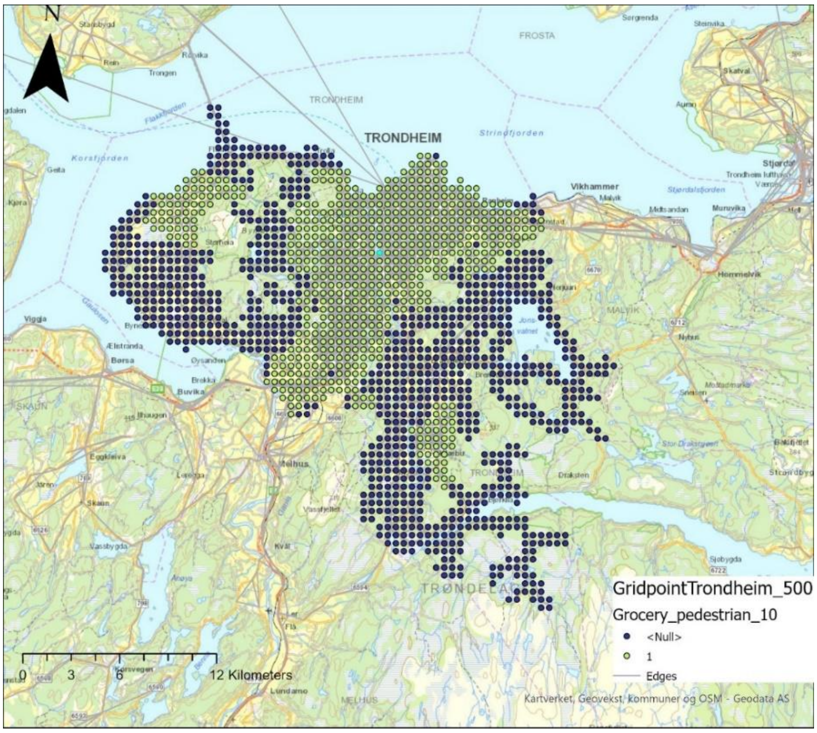
2. Results

2.1.1 Accessibility to grocery store in 5 minutes by Bike

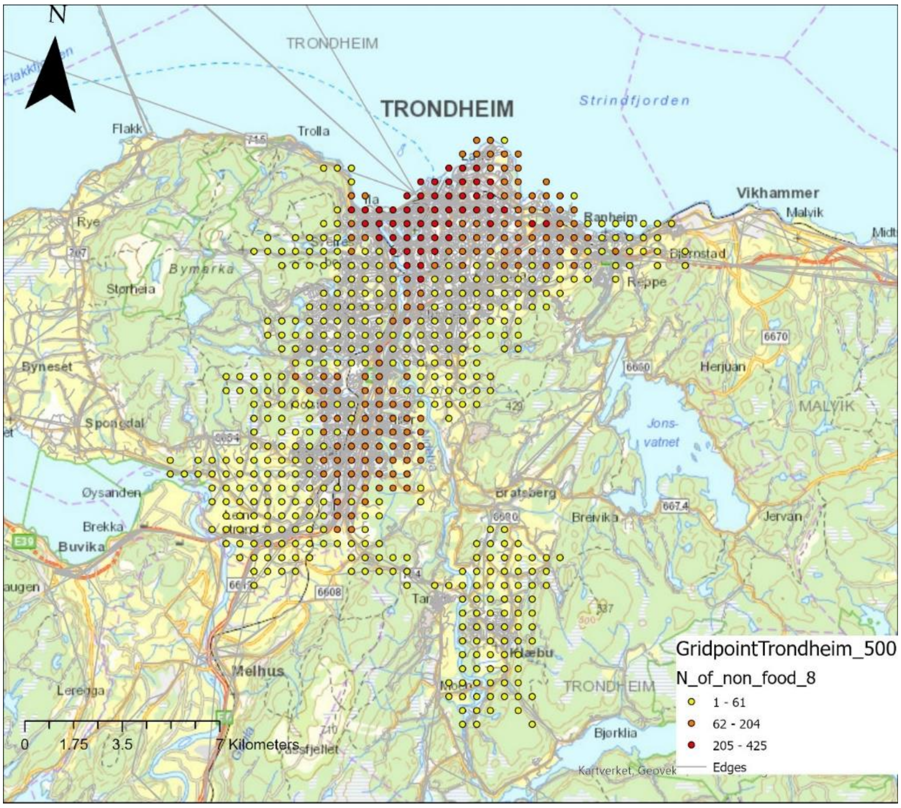


2.1.2 Accessibility to grocery store in 10 minutes by Walking

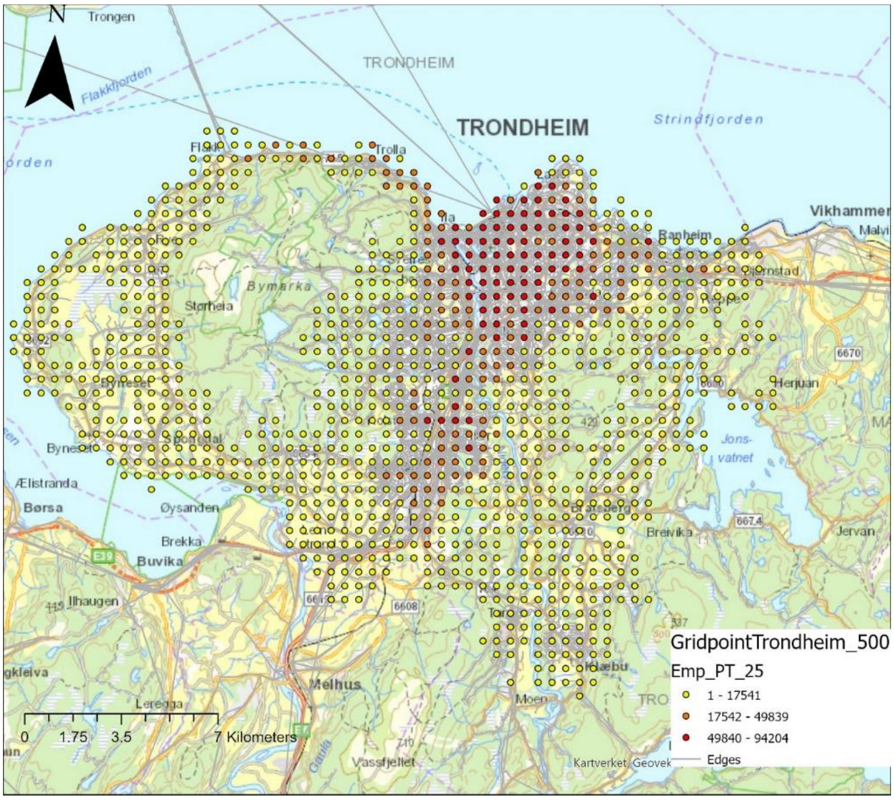
Area under the green points is accessible in the given time.



2.2 Accessibility to non-food stores by car in 8 minutes (With additional time of 3 minutes for parking/Walking)

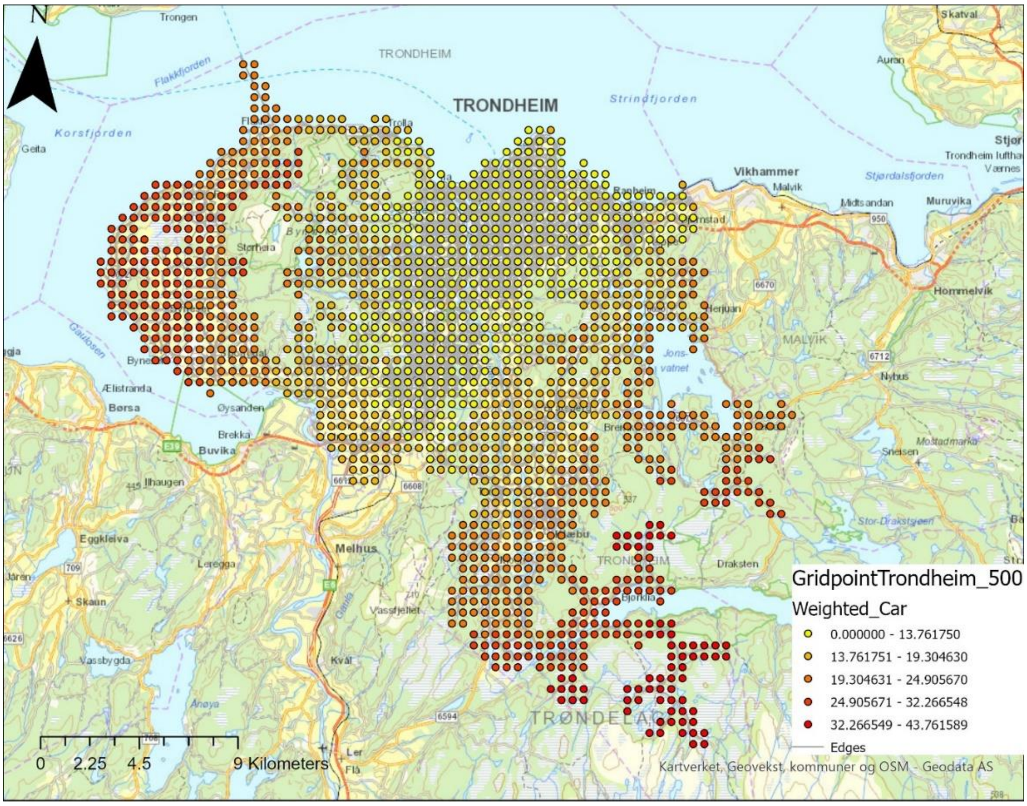


2.3. Employees that can be reached within 25 minutes at 11/11/2020 at 7:30

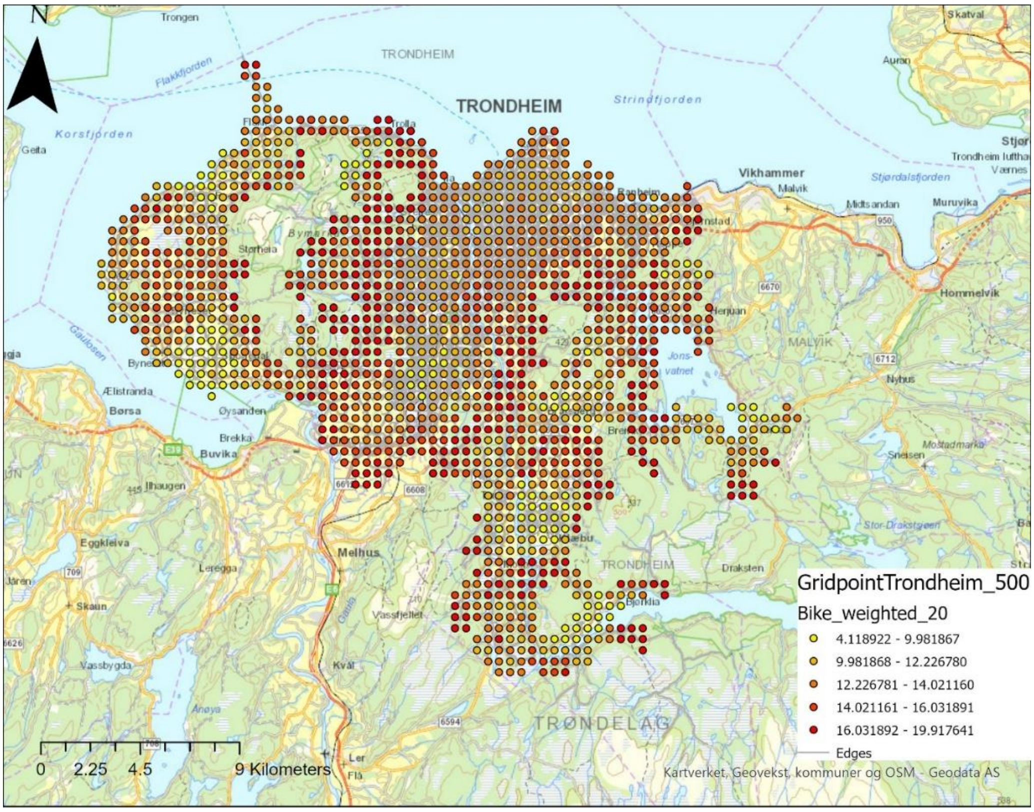


2.4 Average weighted travel time for whole municipality

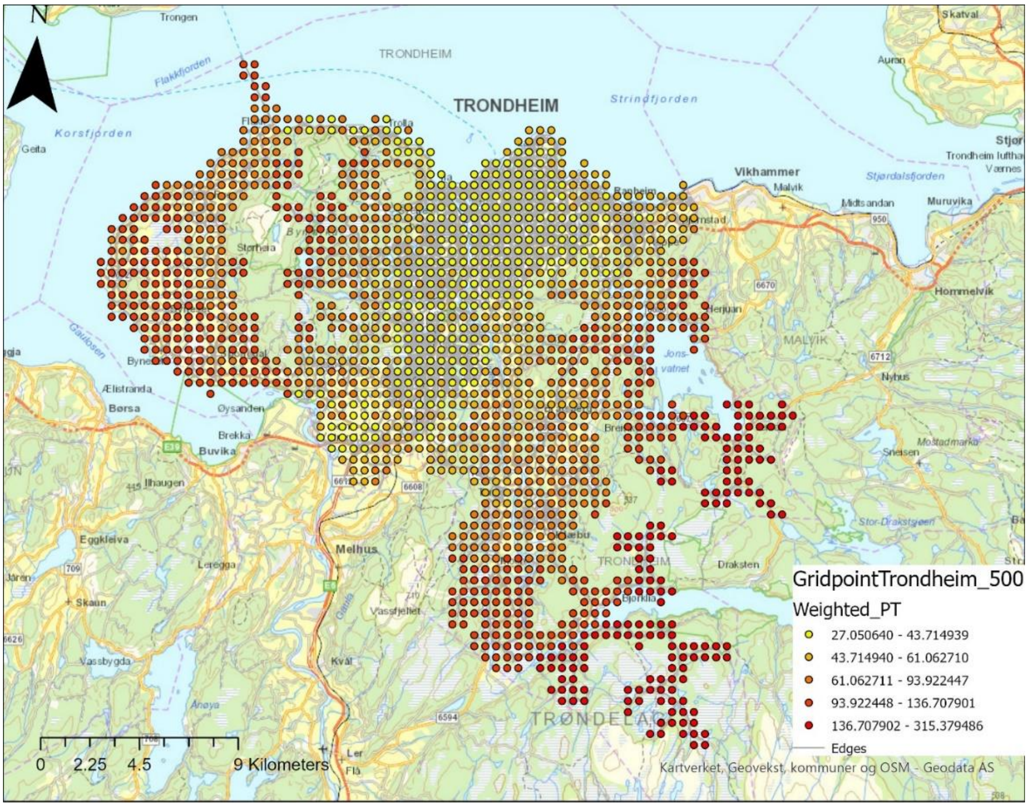
2.4.1. Car



2.4.2. Bike – With a cut-off of 20 mins



2.4.3. PT at 11 November 2020 at 08:00 AM

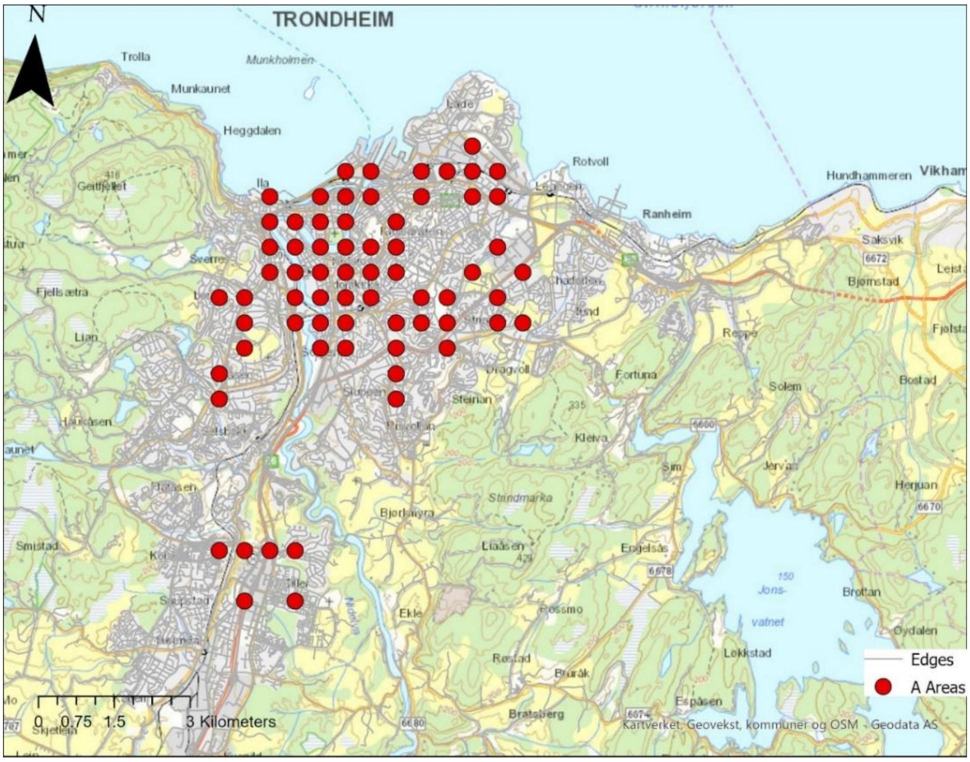


2.5 Creating ABC Map

The Average weighted times calculated for cars, bike (with a cutoff of 20 mins) and for public transport (11/11/2020 at 08:00 AM) were used to create the ABC Map.

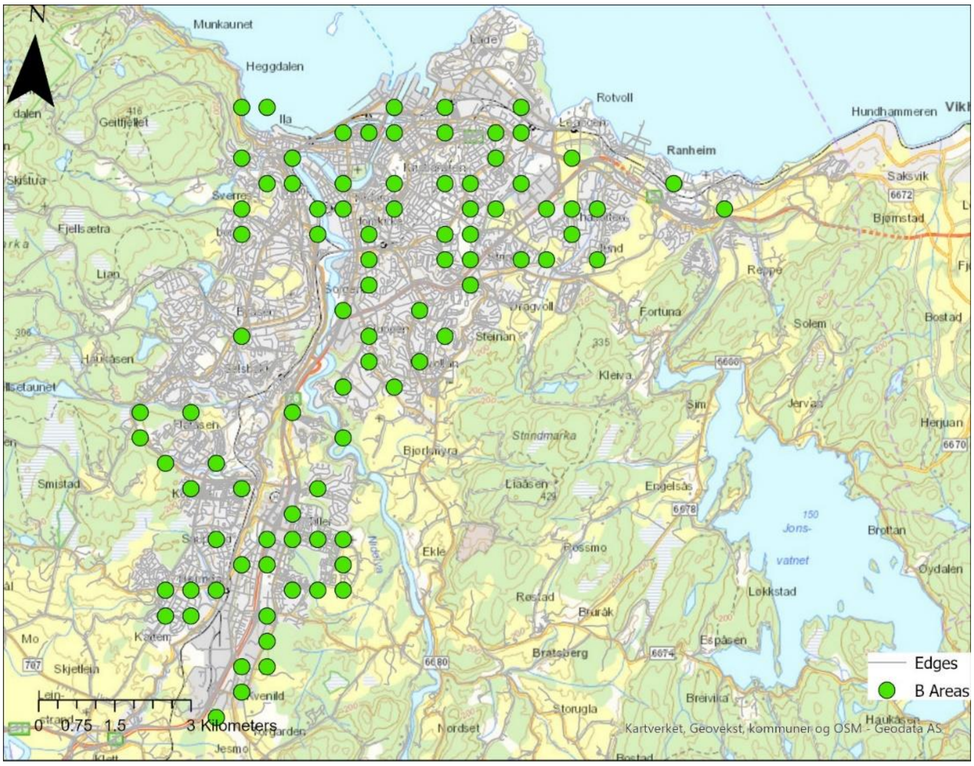
2.5.1 A areas

Weighted Travel Time for PT = 35 minutes and for Bike = 13 minutes



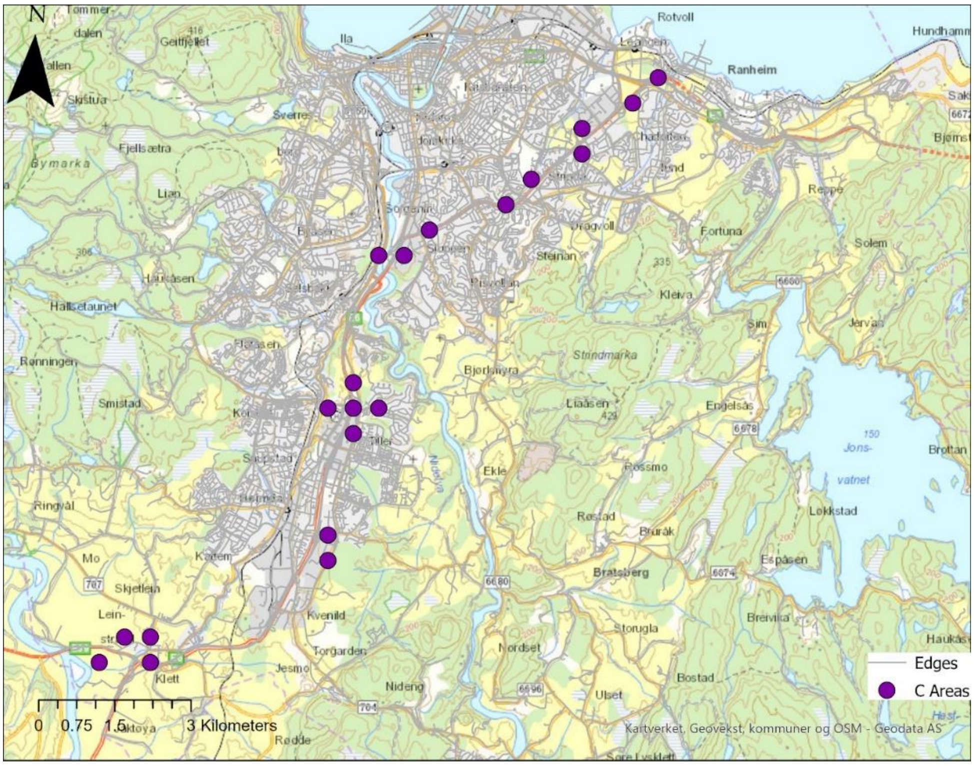
2.5.2 B areas

Closer than 300m to bus stops with frequency > 10 and Weighted Travel Time for PT = 60 minutes and Bike = 15 minutes



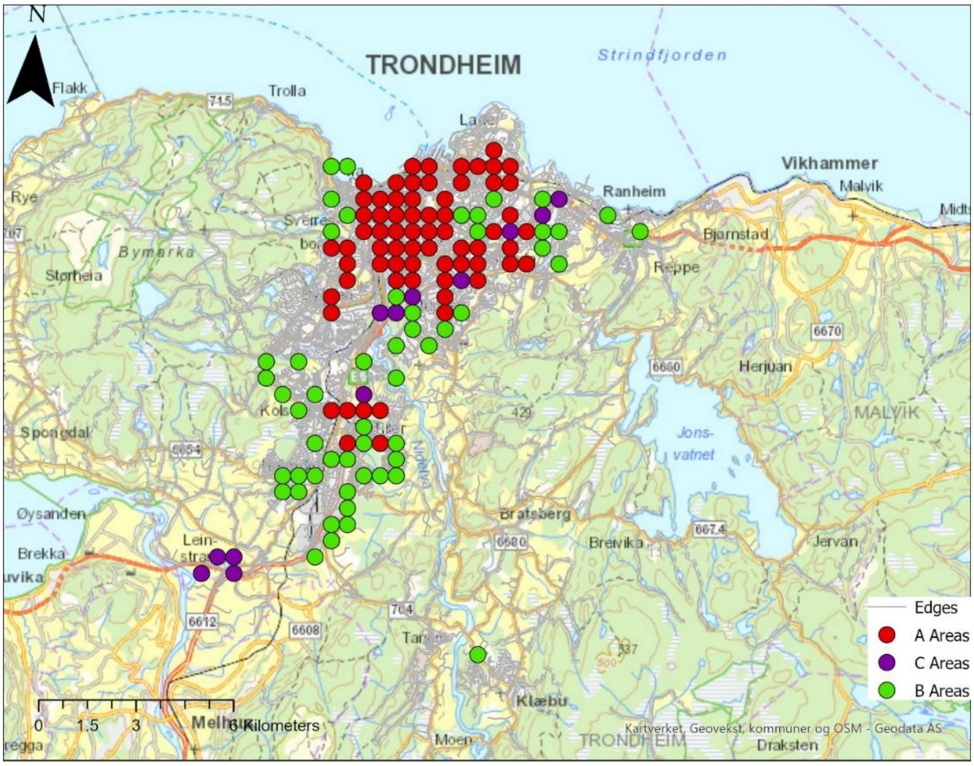
2.5.3 C Areas

Closer than 1000m to 8 intersections on main roads (Vegtype E or R)



2.5.4 ABC Map

Combined ABC map for Trondheim



EXERCISE 5

Raster Modelling

Pedestrian Accessibility

Exercise 5: Raster Modelling
Pedestrian Accessibility

1. Tools and Data Used -

1.1. Database –

a) primary schools point feature class

b) Bus stops with high frequency point feature class

c) Grocery stores point feature class

d) Cost raster for impedance

e) Hraster digital terrain model

f) Mask Raster where movement is prohibited

g) Resistance (Based on Tobler's Model)

h) Resistance-Alt (Slower speed model)

1.2. Tools –

Path Distance Analysis

2. Results

2.1. Raster Model for Pedestrian accessibility

2.2 Access to destination points: grocery shops or retail/non-food

Normal Speed Model (Resistance) was used for average adult while a slower speed model was selected for elderly people (Resistance_alt).

The areas marked in Yellow are accessible in the given time.

We see that the access is less for Fig.2 (Elderly) as the speed model selected is slower.

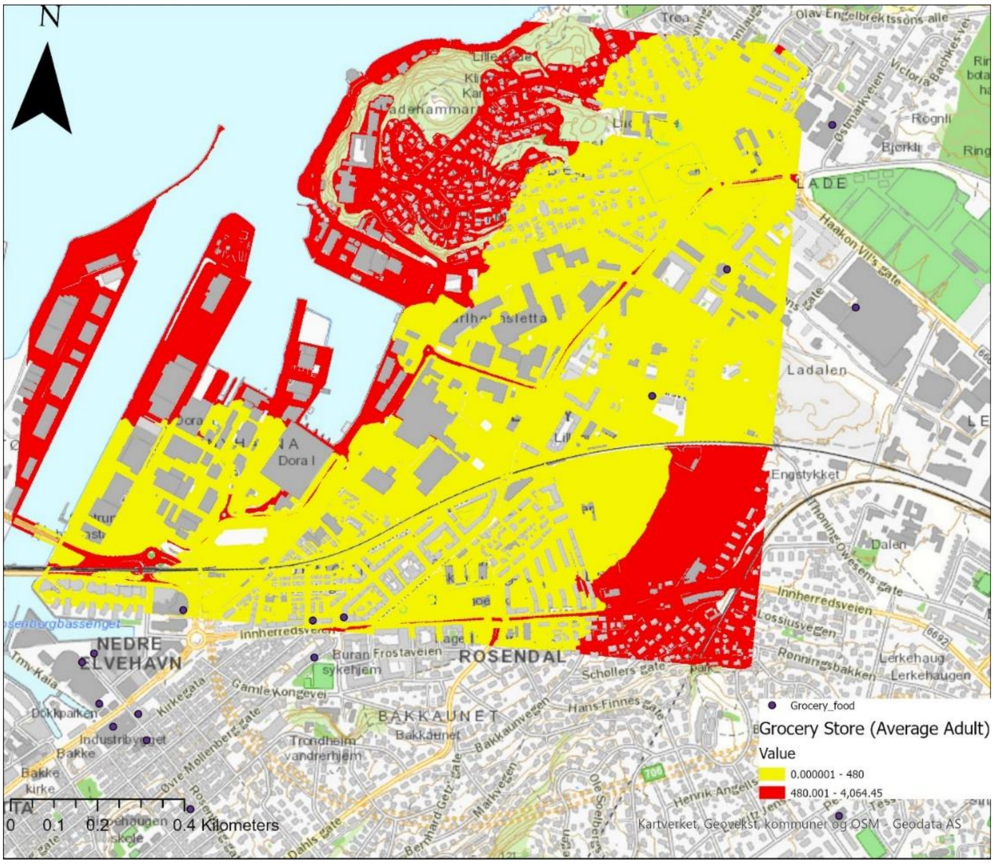


Fig 1. Access to grocery stores in 8 minutes by Walking (Average Adult)

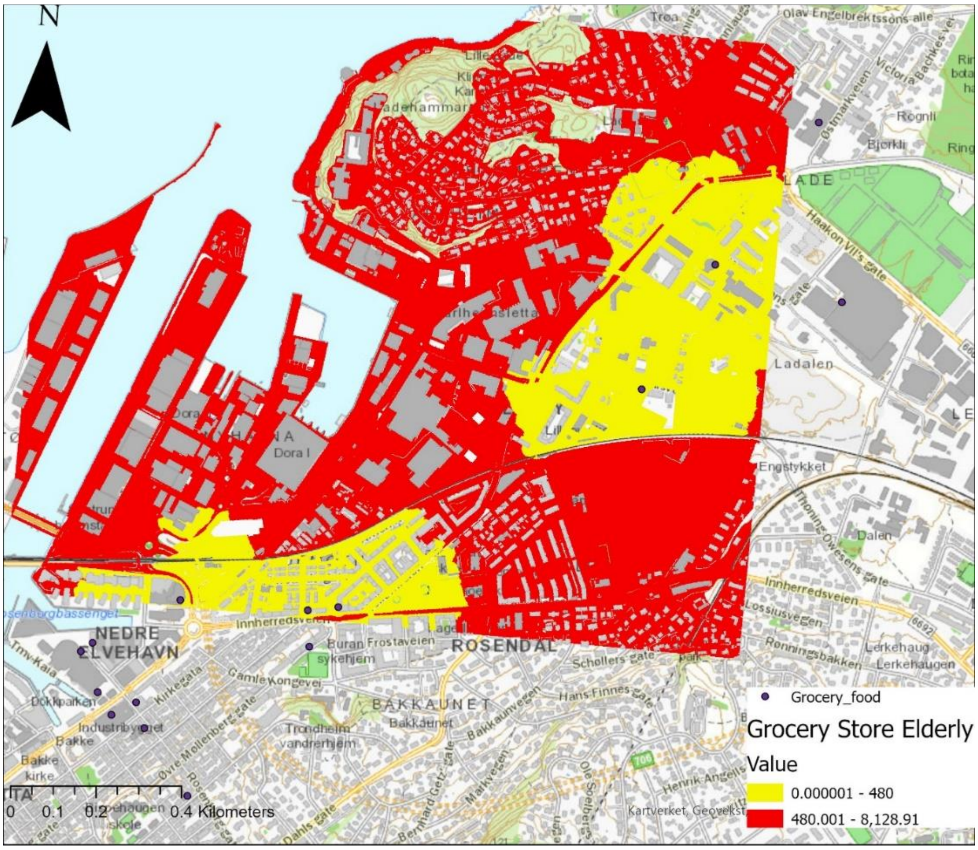


Fig 2. Access to grocery stores in 8 minutes by Walking (Elderly)

2.3 Access to destination points: primary schools

A slower speed model was selected for children (Resistance_alt).

The areas marked in Yellow are accessible in the given time.

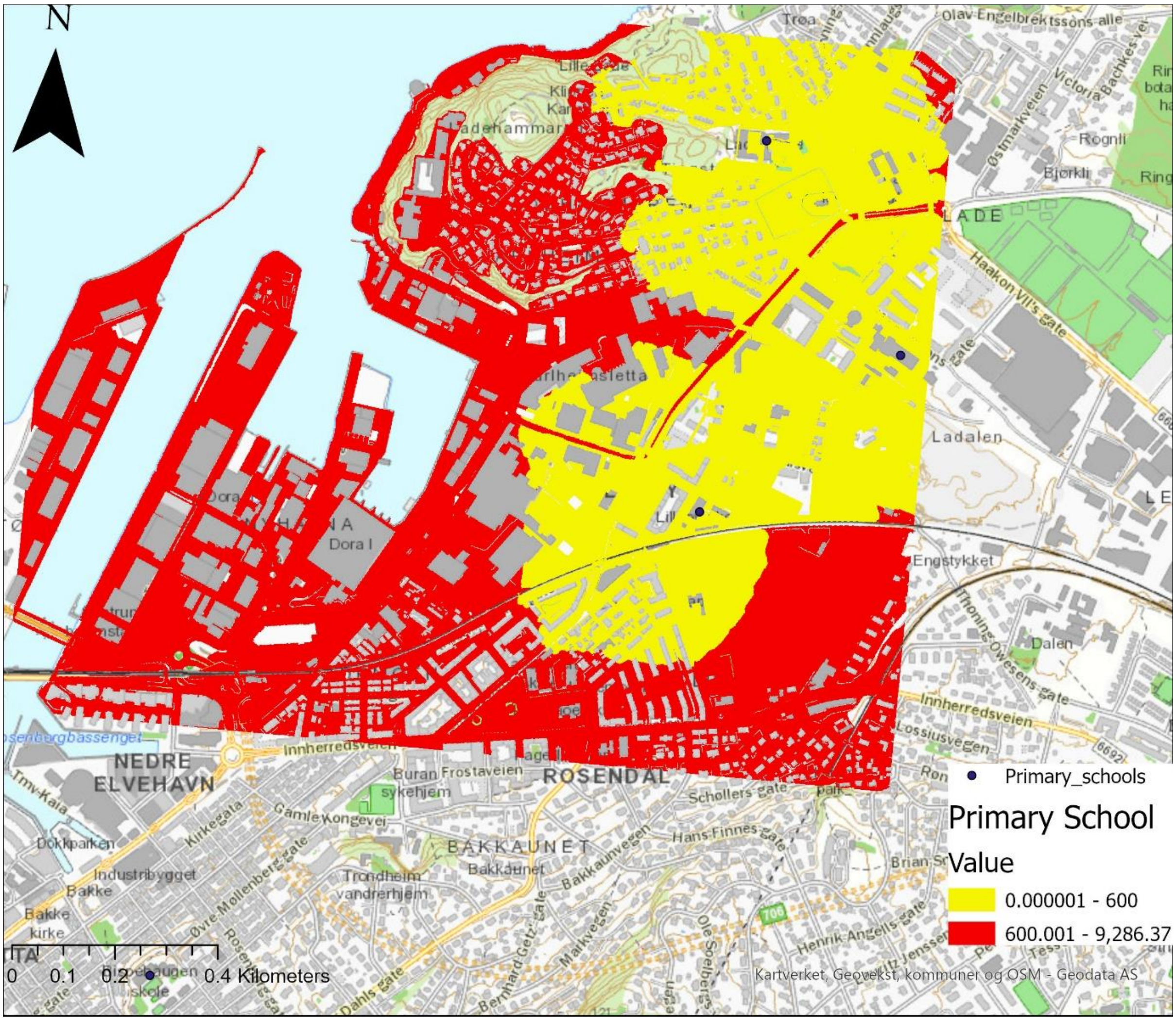


Fig 3. Access to primary schools by walking in 10 minutes (Children)

2.4 Access to destination points: bus stops with high frequency departures

High frequency for bus stop was selected as 10 or more and a normal speed model was selected.

The areas marked in Yellow are accessible in the given time.

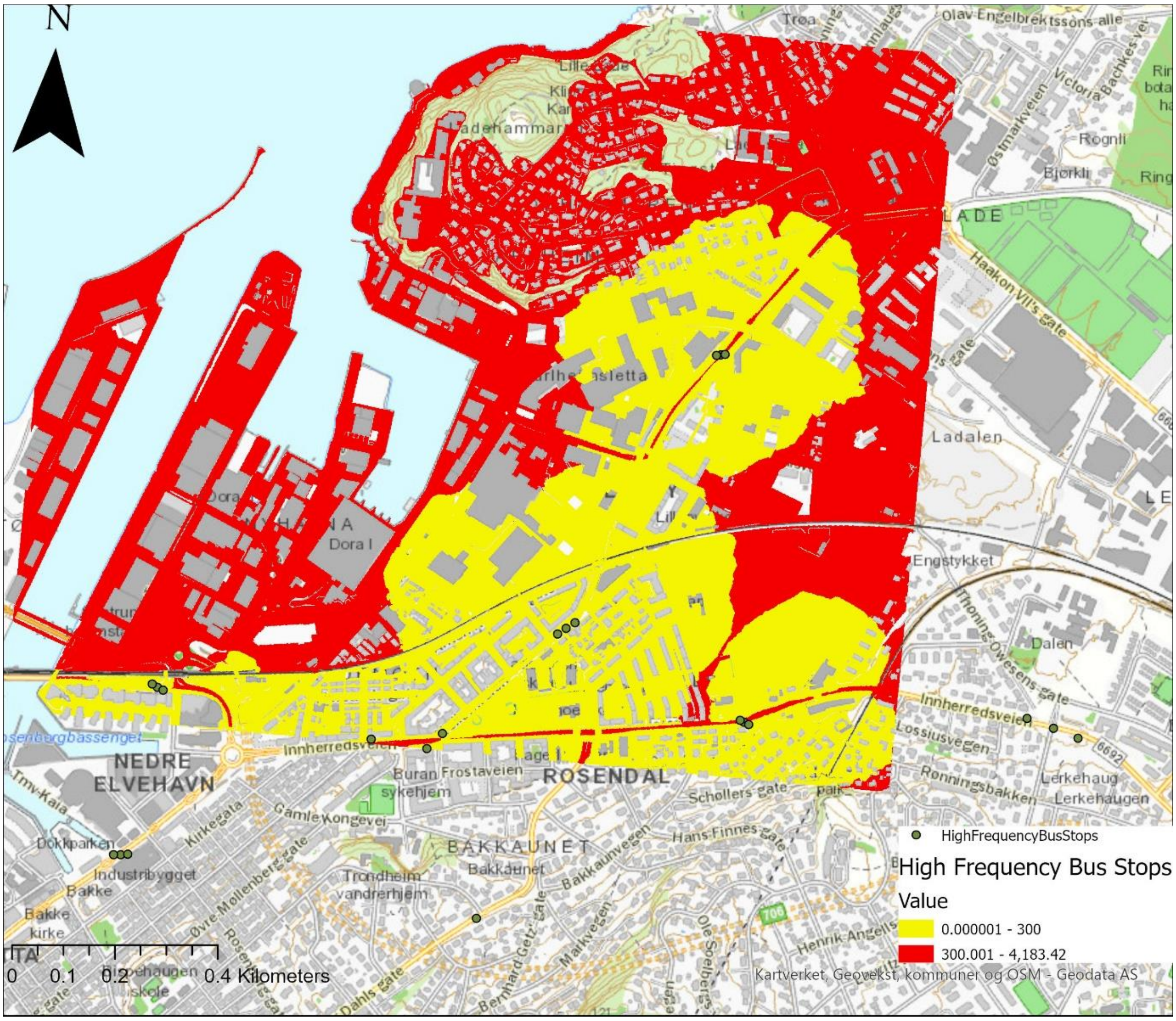


Fig 4. Access to high frequency bus stops by walking in 5 minutes