REPORT:

HyPos – Work Package 3: Positioning with 5G

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HyPos – Work Package 3: Positioning with 5G

Contents

1 Introduction

This report contains results and documentation for work package 3 about positioning with 5G in the HyPos project. HyPos project goal is to explore positioning with scalable high precision GNSS positioning and real time positioning with 5G, and how these technologies can be combined to a hybrid positioning service that utilize the advantages of each technology.

The project has investigated scalable high precision GNSS positioning in work package 2, and this report contains information about real time positioning with 5G.
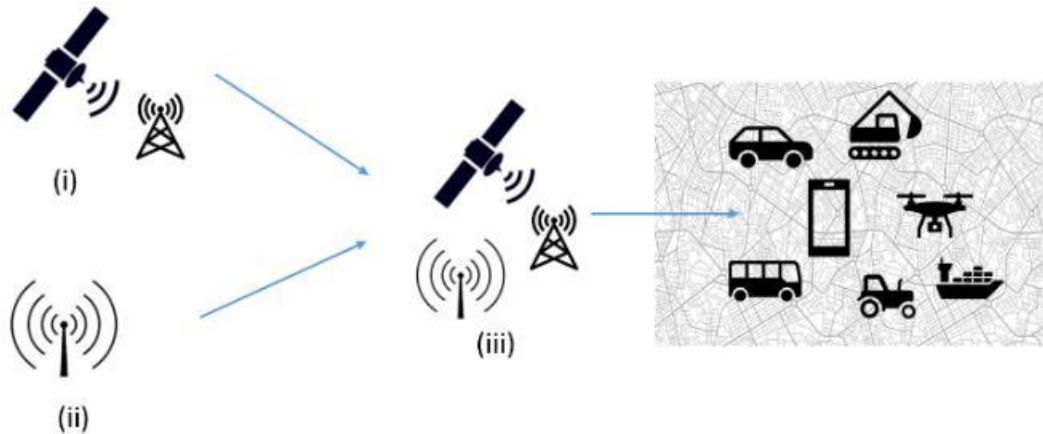

Figure 1: Concept of HyPos: (i) Scalable high precision GNSS service (ii) Positioning with 5G (iii) Hybrid positioning service and user group

2 Enabling real time positioning with telecom network

Two telecom base stations at Kista, Stockholm, were upgraded to be able to use the latest advancements of 5G positioning within the NorthStar network [1]. Position determination relies on measuring both the distance and angle between a base station and a 5G-enabled device. Consequently, the exact coordinates of each base station must be known. Using these coordinates, polar measurements are applied to calculate the device's position at the positioning server. All 5G position data for the capture device is stored for exposure to network applications and saved in log files.

SSR GNSS corrections were enabled from telecom base stations by use of 3GPP standardisation to achieve GNSS positions at sub 5cm level. GNSS positions for the data capture device are reported to the positioning server and stored for exposure to network applications and saved in log files.

3 Data capture

Data captures were conducted at Kista, Stockholm, by use of a 5G enabled router and a GNSS receiver as a capture device. The GNSS positions have an accuracy of sub 5cm and are used as reference positions versus the 5G positions. Data captures were done in an area served by two sites at Kista, using positioning measurements from one base station to calculate the 5G positions.

The area was divided into two subareas, each served by one of the 5G base stations. As illustrated by Figure 2, 5 static test locations were used in the first subarea (left), while 11 test locations were used in the second subarea.
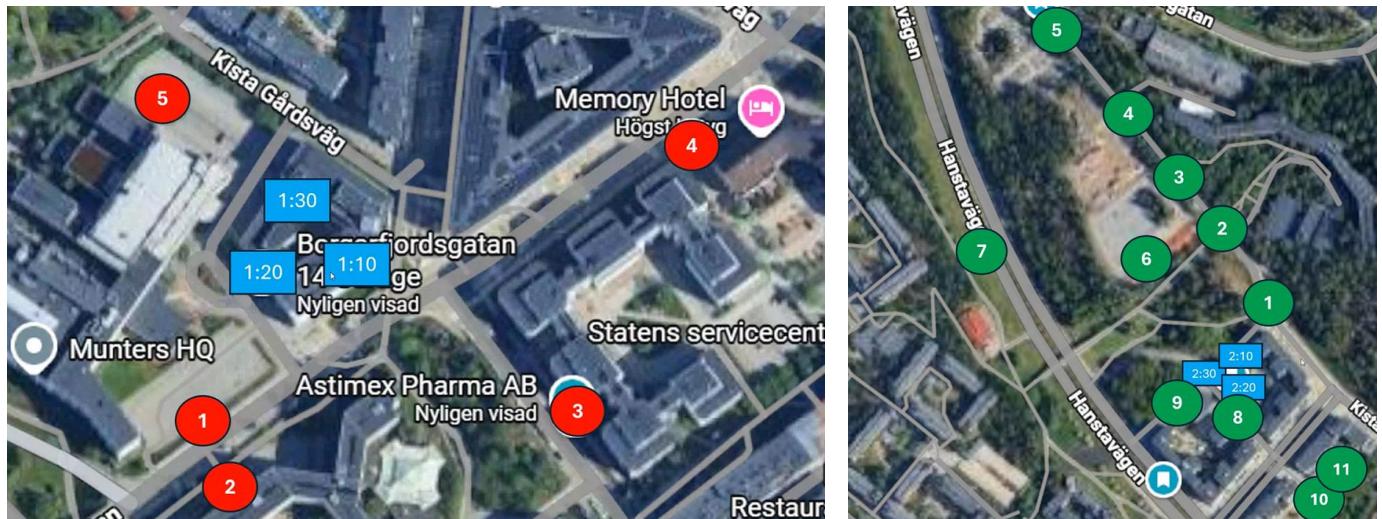

Figure 2: Static test locations for the first (left) and second (right) subareas, each served by different base stations.

In addition, 8 successful drive test was conducted in the area next to or between the static test locations, both inside the respective subarea and between subareas.

4 Analysis and results

Two test campaigns were conducted, one in the morning and on in the afternoon, both containing static and drive tests.

4.1   Static tests

Static tests were conducted by standing still at a test location and measuring positions for a couple of minutes, both with GNSS and with 5G/mobile positioning.

In this section the results from all the static tests are listed. For every test, first the base station site is given, second, the defined test location shown in Figure 2, and third, for which test campaign (morning or afternoon). This is followed by:

- one plot with the 5G network-based position estimates compared to the mean high accuracy GNSS position estimates (red) in a latitude/longitude plot
- one plot with a histogram of the relative distances in meters between the 5G position estimates and the high accuracy GNSS position estimate.
- one plot with the 5G position estimates and the GNSS position estimates on a map
- a table with distance between the connected base station location and the 5G position estimates, the angle deviation from the 5G position estimate compared to the GNSS position estimate (reference would always be 0 degree), and third, the distance deviation between the 5G position estimate and the GNSS position estimate.

Site 1, test location 1, morning test campaign
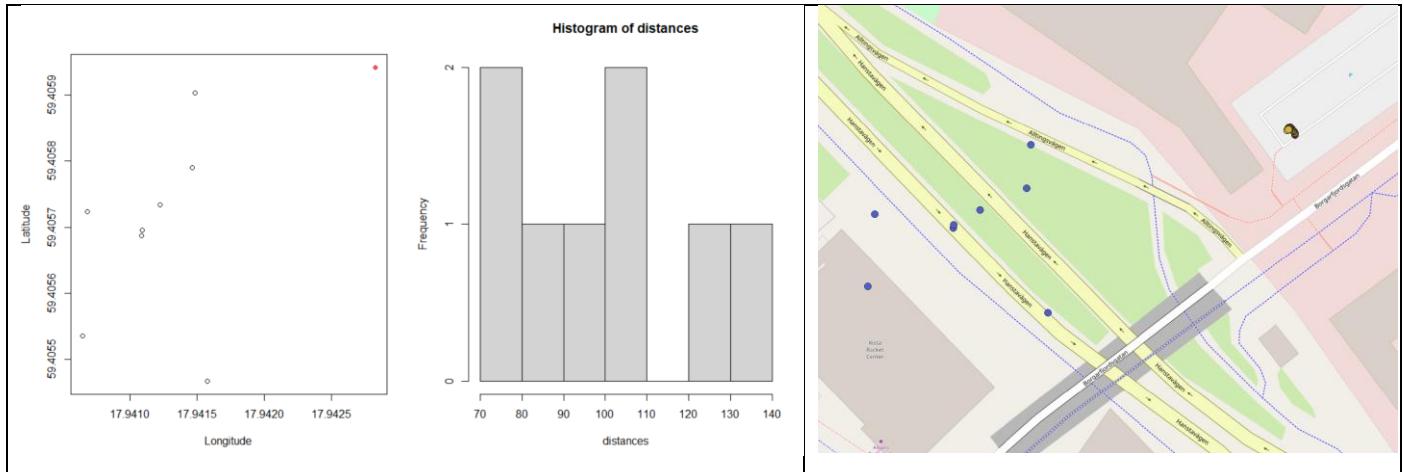
Distance	Angle deviation	Distance deviation
170.6026	35.81187	76.55699
194.6265	26.06940	100.58088
186.5420	32.50915	92.49633

Site 1, test location 1, afternoon test campaign
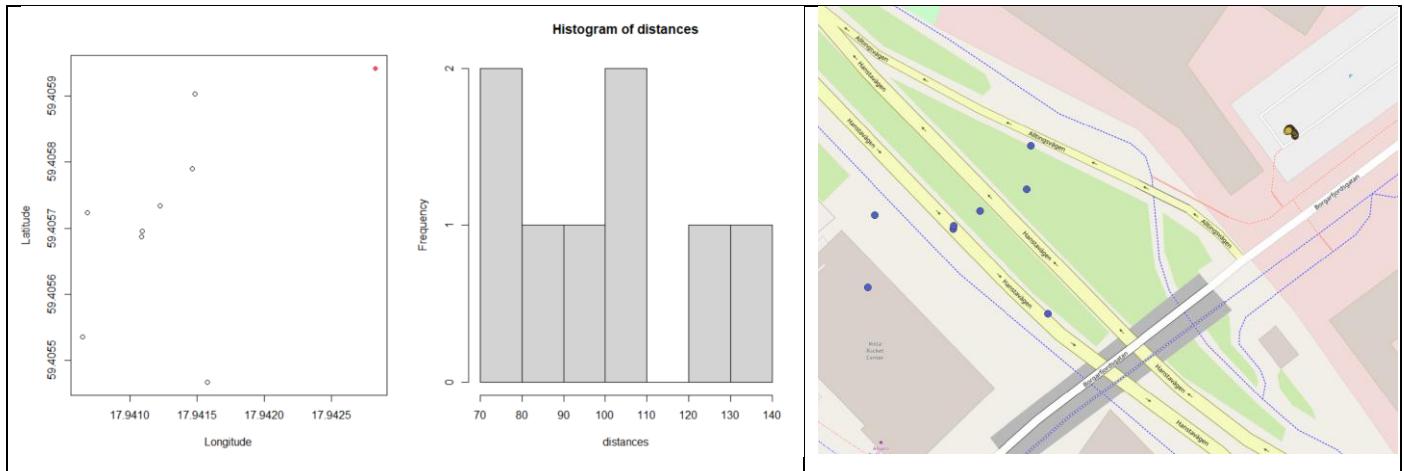
Distance	Angle deviation	Distance deviation
163.2321	19.484871	62.09242
195.0191	16.596099	93.87938
185.6802	16.683995	84.54051
225.0150	16.394358	123.87526
188.4074	5.741659	87.26767
194.3994	16.817354	93.25974
170.7989	15.997230	69.65924
212.6150	20.846538	111.47534

*Site 1, test location 1 – slightly more south, afternoon test campaign*
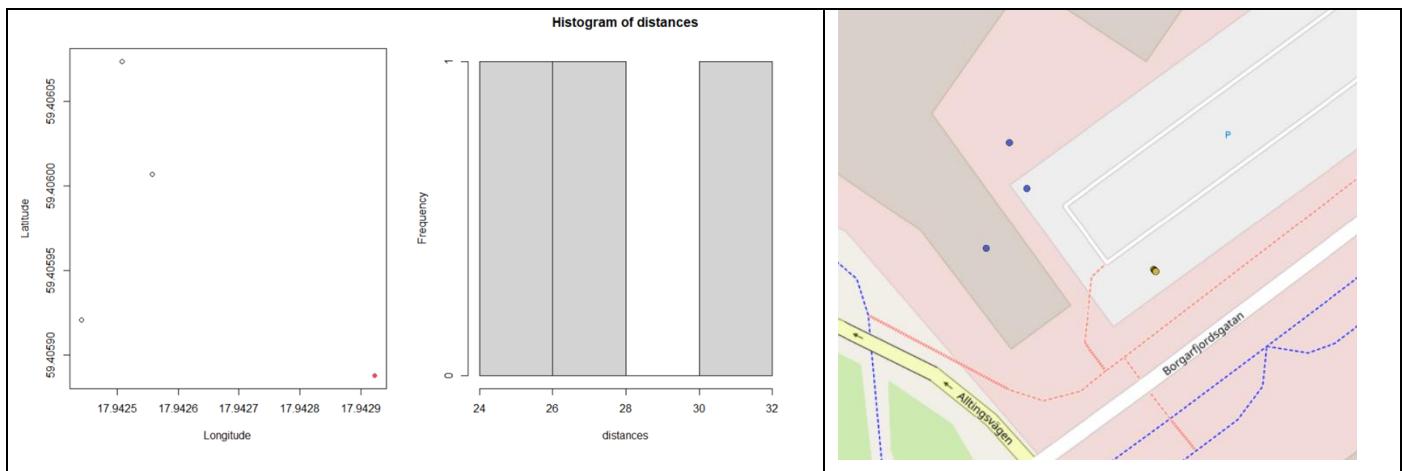
Distance	Angle deviation	Distance deviation
118.0197	11.79317	15.607676
106.7288	13.26347	4.316777
104.3291	17.36928	1.917163

Site 1, test location 2, morning test campaign
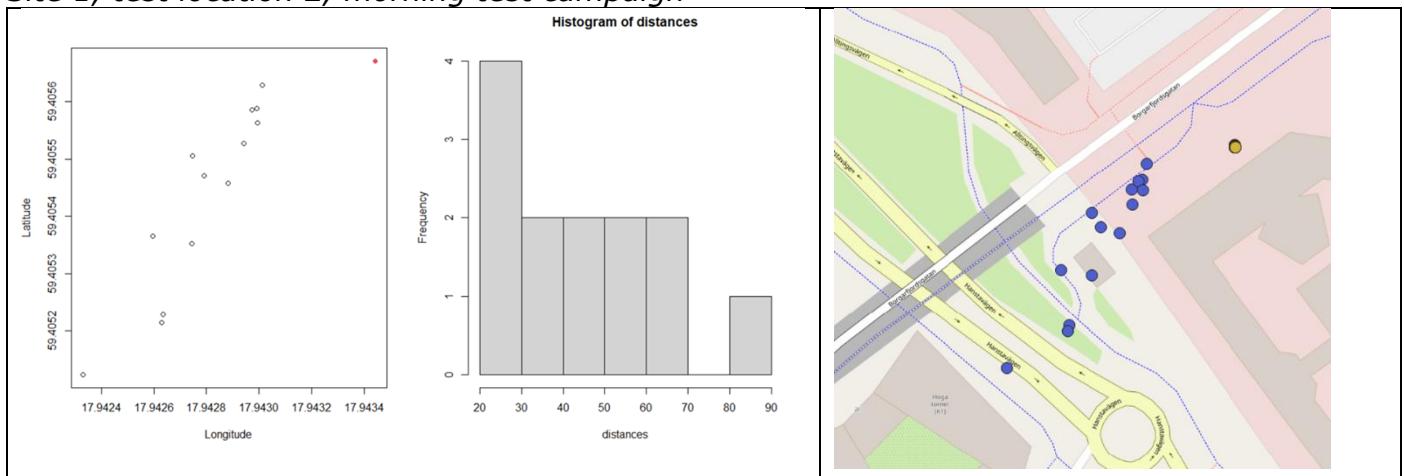
Distance	Angle deviation	Distance deviation
128.9842	9.751417	17.82024
136.3985	9.550381	25.23454
129.7429	10.147023	18.57897
145.8372	11.548896	34.67319
131.4440	9.160017	20.27999
158.7651	10.158878	47.60110
173.7753	9.954969	62.61136
192.2464	13.033914	81.08239
124.4625	10.151766	13.29848
144.8545	9.458948	33.69050
175.3753	9.850319	64.21131
161.4197	13.050998	50.25572
143.5815	13.143371	32.41752

Site 1, test location 2, afternoon test campaign
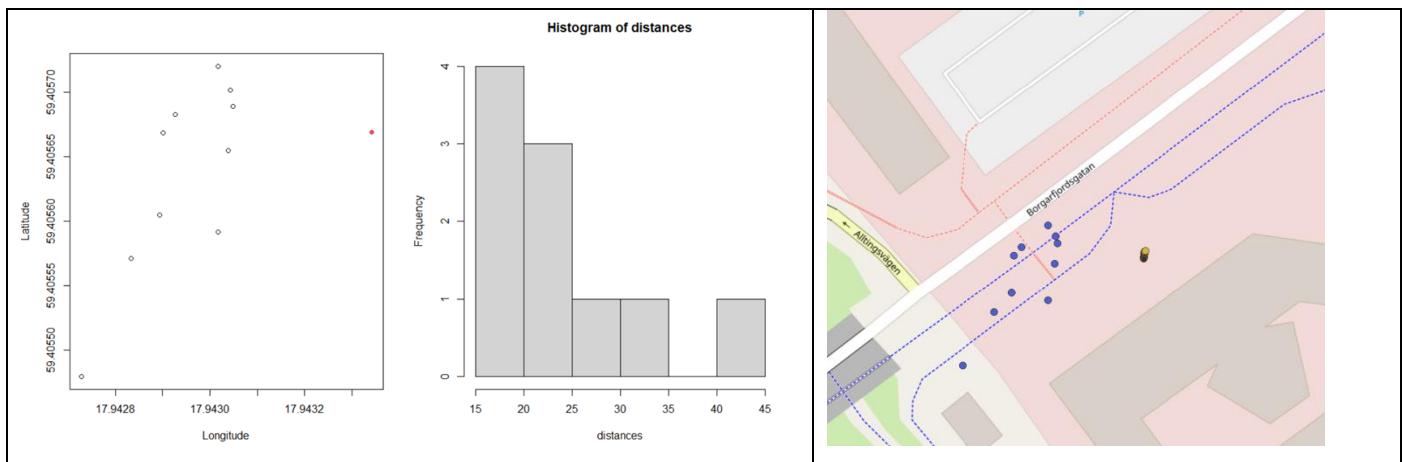
Distance	Angle deviation	Distance deviation
123.5617	11.021349	10.437915
129.9501	9.633436	16.826365
121.2020	7.445760	8.078277
128.0854	6.559046	14.961580
116.4244	8.504580	3.300611
121.4101	10.796263	8.286316
115.3047	9.627099	2.180885
134.8365	10.131814	21.712685
117.5379	8.037648	4.414166
146.6621	10.224087	33.538290

Site 1, test location 3, morning test campaign
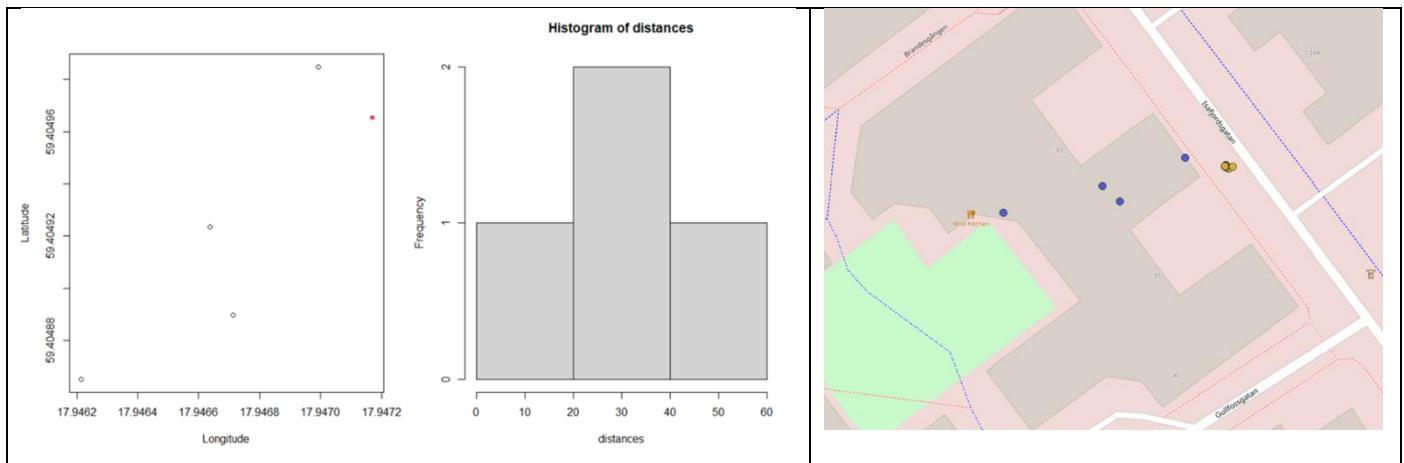
| Distance	Angle deviation	Distance deviation
233.4359	11.504817	-24.968883
242.0391	5.886001	-16.365729
249.9209	1.299760	-8.483886
247.6256	5.659621	-10.779174

Site 1, test location 3, afternoon test campaign
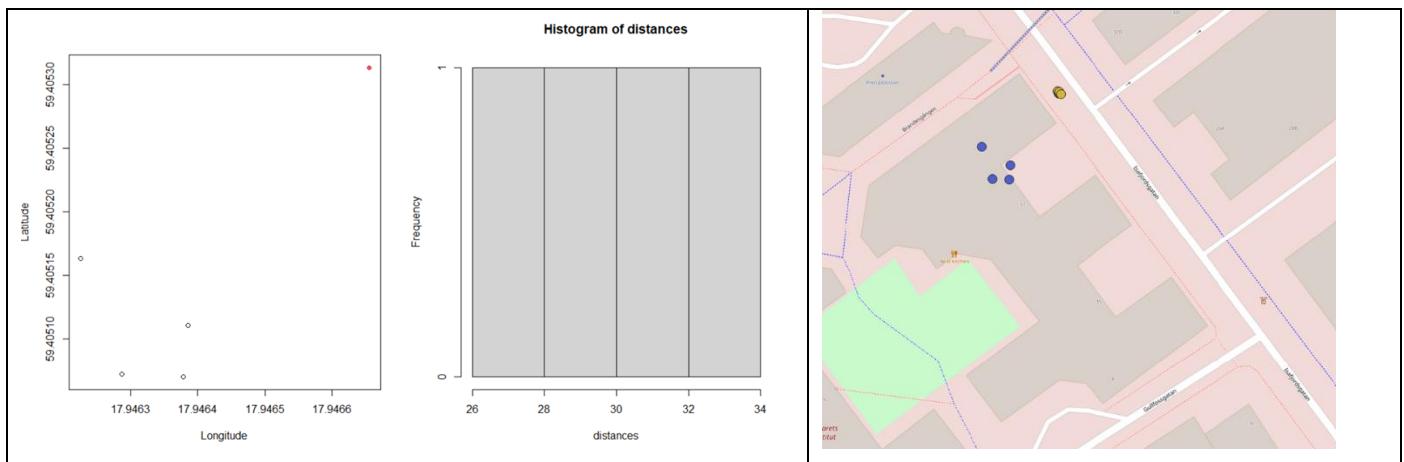
Distance	Angle deviation	Distance deviation
206.6749	8.037509	-3.737317
220.1500	7.917241	9.737833
216.8763	7.097185	6.464168
216.7819	8.955927	6.369767

Site 1, test location 4, morning test campaign
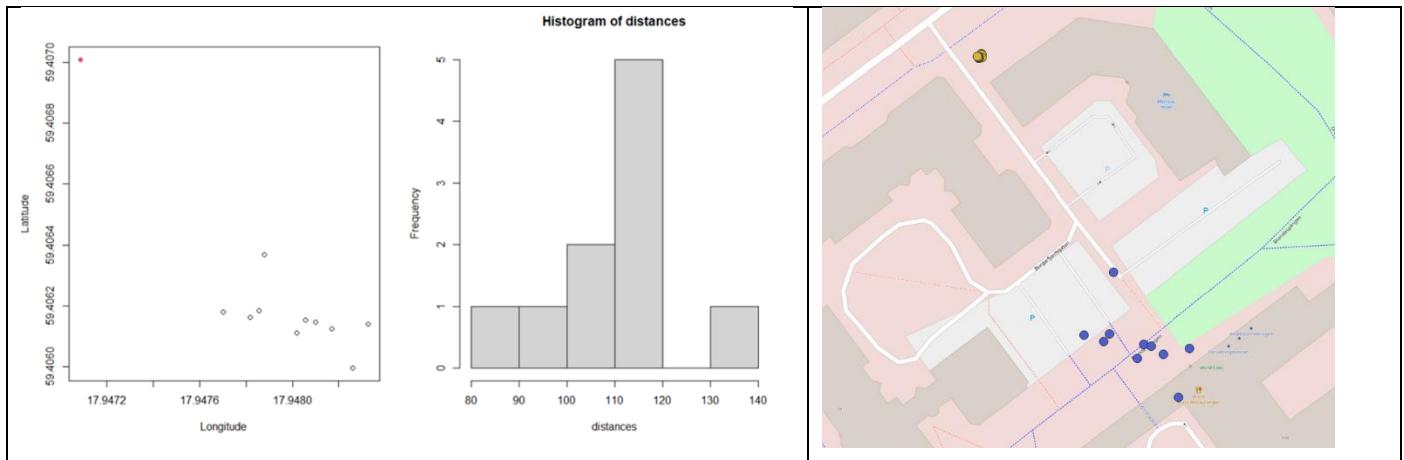
Distance	Angle deviation	Distance deviation
252.0622	29.79891	71.50009
224.5509	26.31309	43.98884
223.1561	27.01831	42.59408
216.2702	26.91268	35.70814
235.4804	27.71510	54.91836
243.4551	26.91020	62.89305
222.2282	21.05094	41.66609
236.3858	26.52006	55.82369
238.9717	26.52006	58.40963
251.5800	26.02125	71.01796

Site 1, test location 4, afternoon test campaign
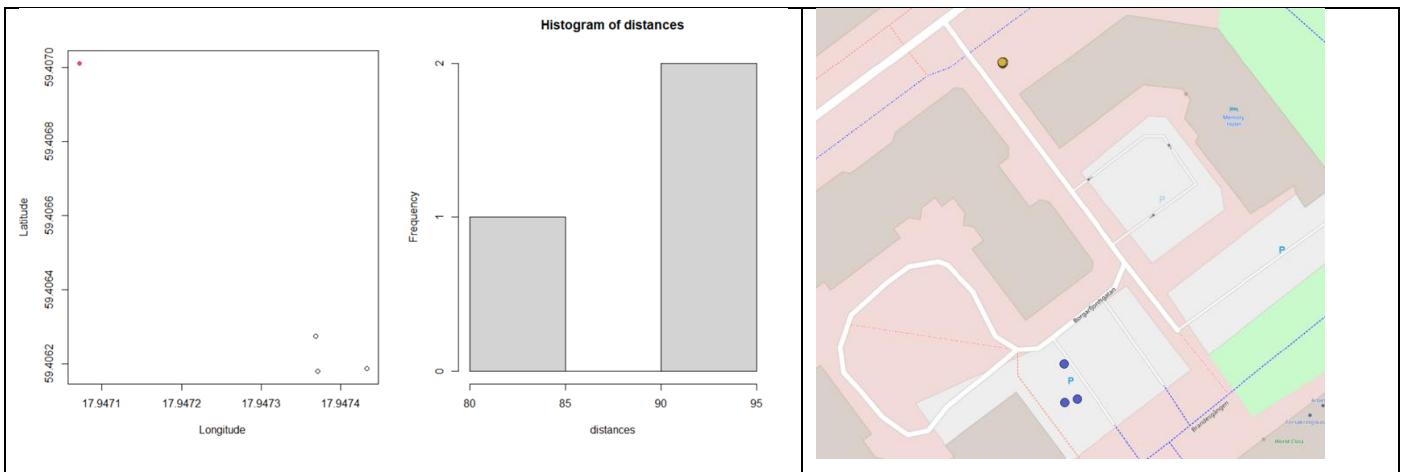
Distance	Angle deviation	Distance deviation
195.4591	25.35838	15.73579
197.9996	28.33144	18.27629
201.1631	27.83318	21.43988

Site 1, test location 5, morning test campaign
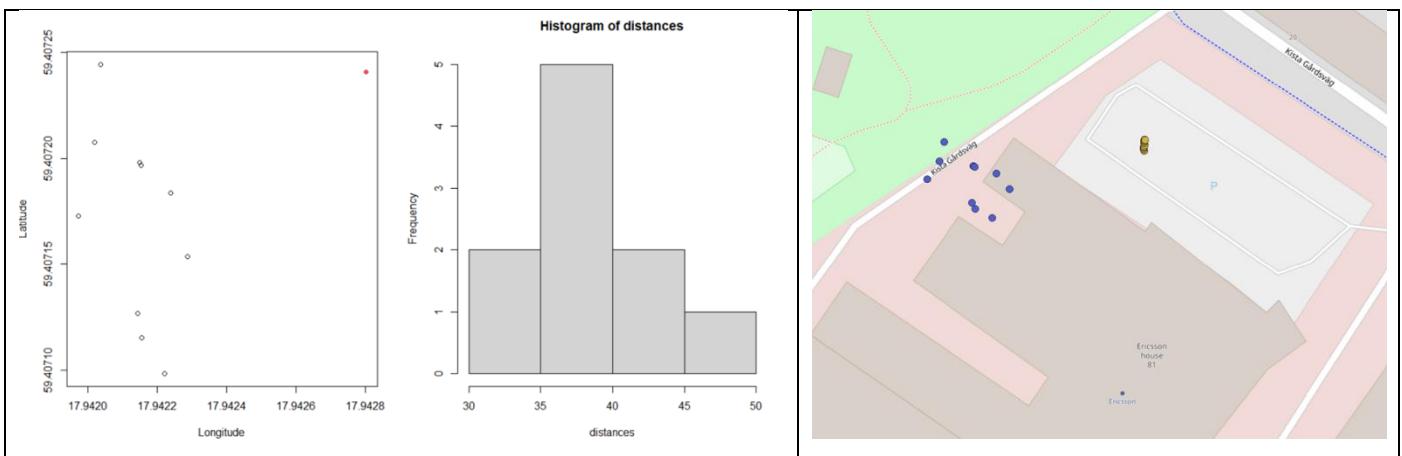
Distance	Angle deviation	Distance deviation
129.2604	-17.38250	33.54960
128.8505	-15.30710	33.13972
116.8523	-13.42827	21.14153
117.1313	-17.77878	21.42048
118.3480	-17.38331	22.63723
112.7477	-14.12047	17.03687
130.0841	-13.52684	34.37329
121.9807	-14.02224	26.26987
113.0182	-17.77830	17.30739
121.6641	-14.02246	25.95325

Site 1, test location 5, afternoon test campaign
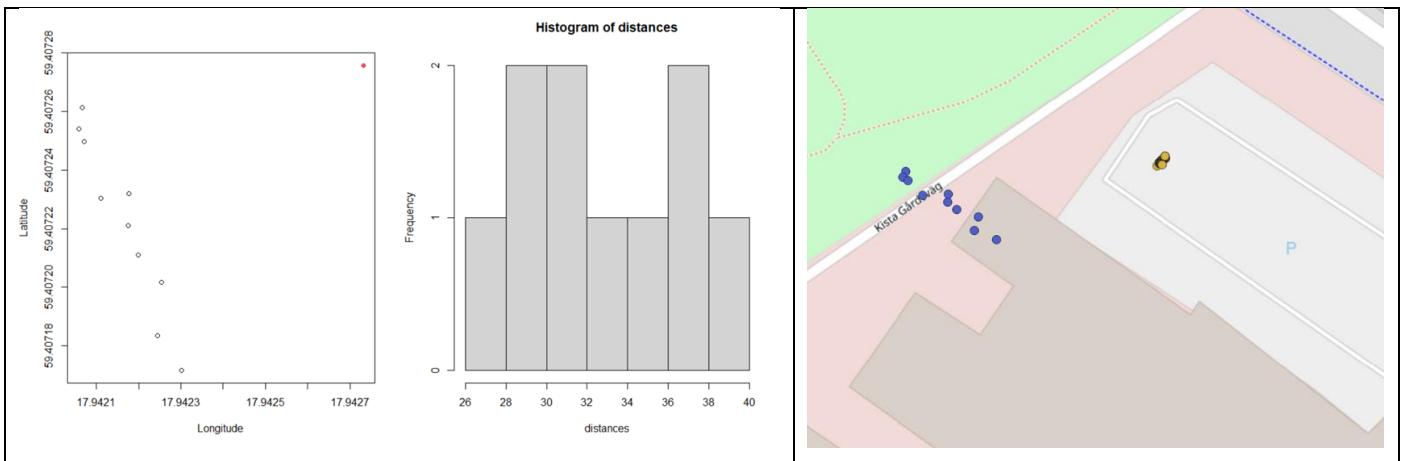
Distance	Angle deviation	Distance deviation
122.0685	-12.62055	20.81138
122.6771	-12.12685	21.41999
129.6905	-12.42204	28.43339
117.1480	-12.32061	15.89086
120.3377	-12.71608	19.08057
116.5017	-13.31033	15.24464
125.6958	-13.11462	24.43865
113.0821	-13.01631	11.82499
129.5929	-12.81539	28.33581
128.7327	-12.81846	27.47563

*Site 2, between test locations 1 and 2, afternoon test campaign*
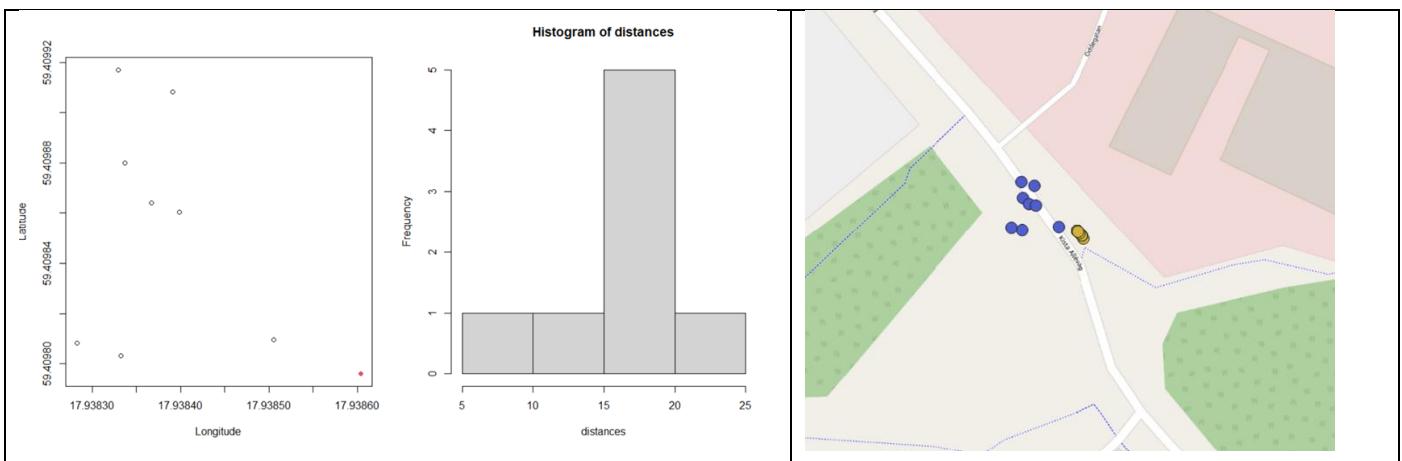
Distance	Angle deviation	Distance deviation
108.4785	-8.081340	-1.1163119
108.9254	-9.568792	-0.6694011
120.3785	-6.798472	10.7837019
117.0364	-8.184607	7.4416028
121.1552	-8.481225	11.5603899
115.3634	-7.293519	5.7686251
115.0950	-6.389996	5.5002273
110.1434	-2.992853	0.5485577

Site 2, test location 2, morning test campaign
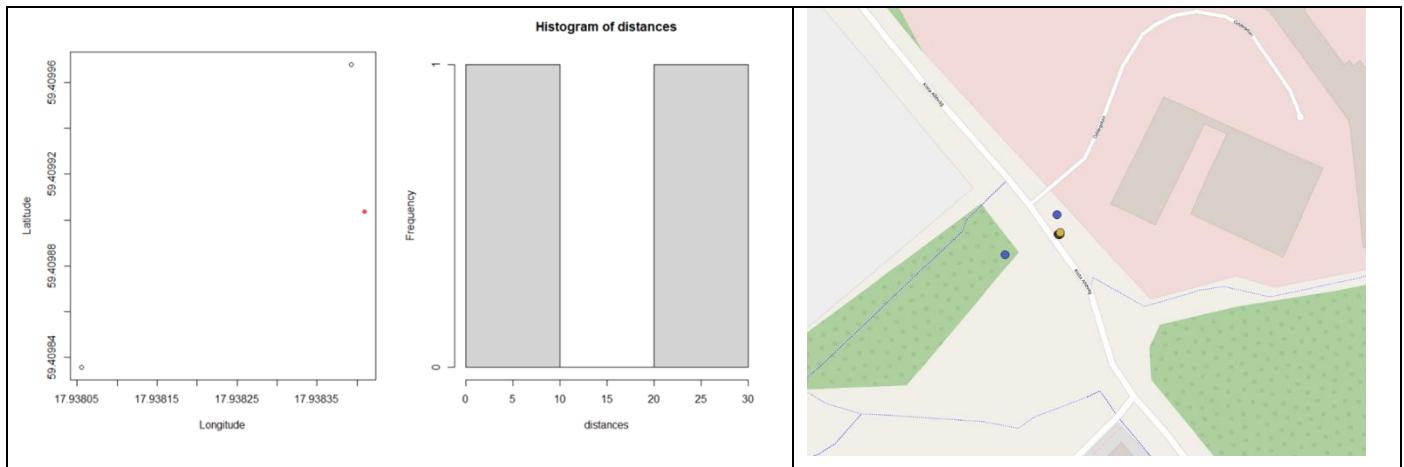
Distance	Angle deviation	Distance deviation
112.3848	-9.9030678	-7.565077
127.0034	-0.6863848	7.053438

*Site 2, between test locations 2 and 3, morning test campaign*
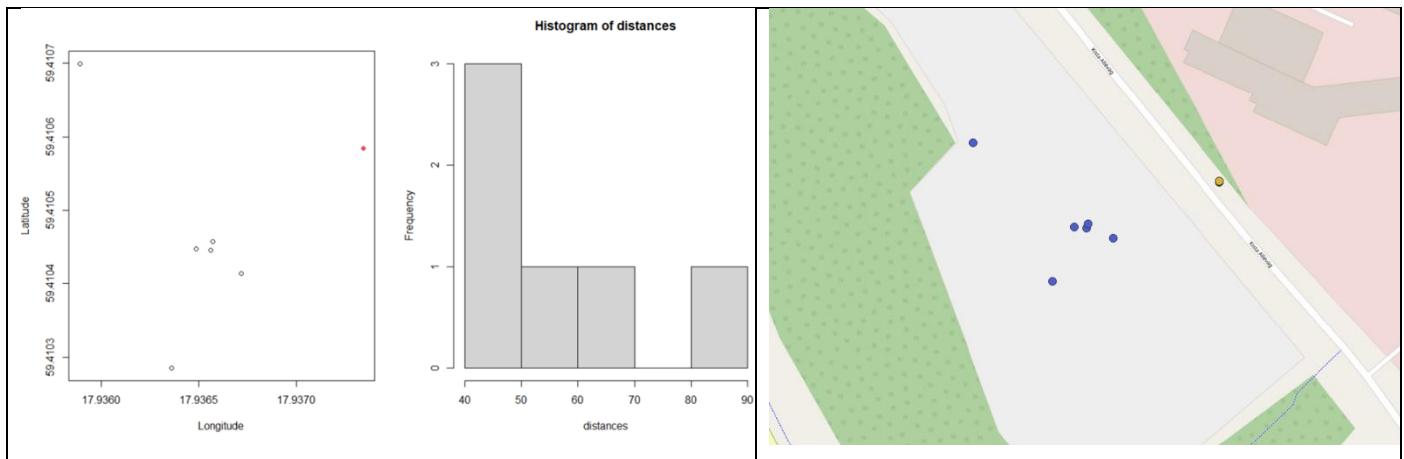
Distance	Angle deviation	Distance deviation
196.0264	-11.48823	-5.610679
246.7505	-18.09237	45.113448
203.1641	-13.34096	1.527011
204.0749	-13.03837	2.437831
205.3086	-14.34017	3.671525
193.5760	-18.80764	-8.061093

*Site 2, between test locations 2 and 3, afternoon test campaign*

Distance	Angle deviation	Distance deviation
290.5955	-20.21915	23.54243
305.5165	-23.84762	38.46336
301.0089	-22.58895	33.95578
307.7751	-16.62729	40.72202
305.2565	-22.69694	38.20337
281.1884	-23.69002	14.13528

Site 2, test location 4, morning test campaign
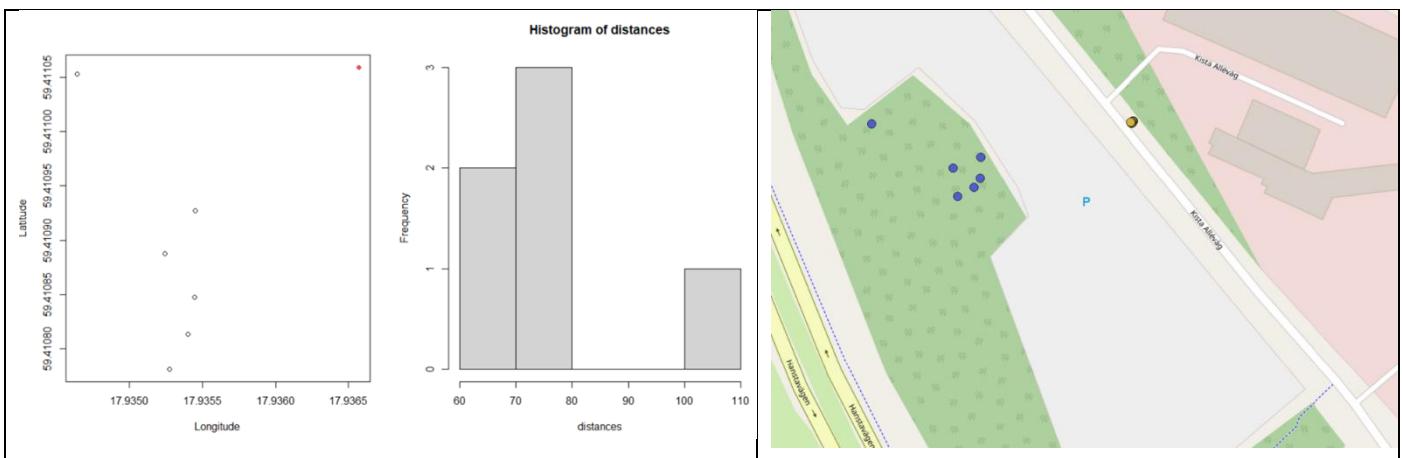
Distance	Angle deviation	Distance deviation
284.7824	-15.70997	19.396375
274.4936	-14.34185	9.107541
274.1943	-16.86468	8.808221
281.5919	-13.25858	16.205804
272.9375	-15.24307	7.551404
320.1922	-18.65417	54.806152

Site 2, test location 4, afternoon test campaign
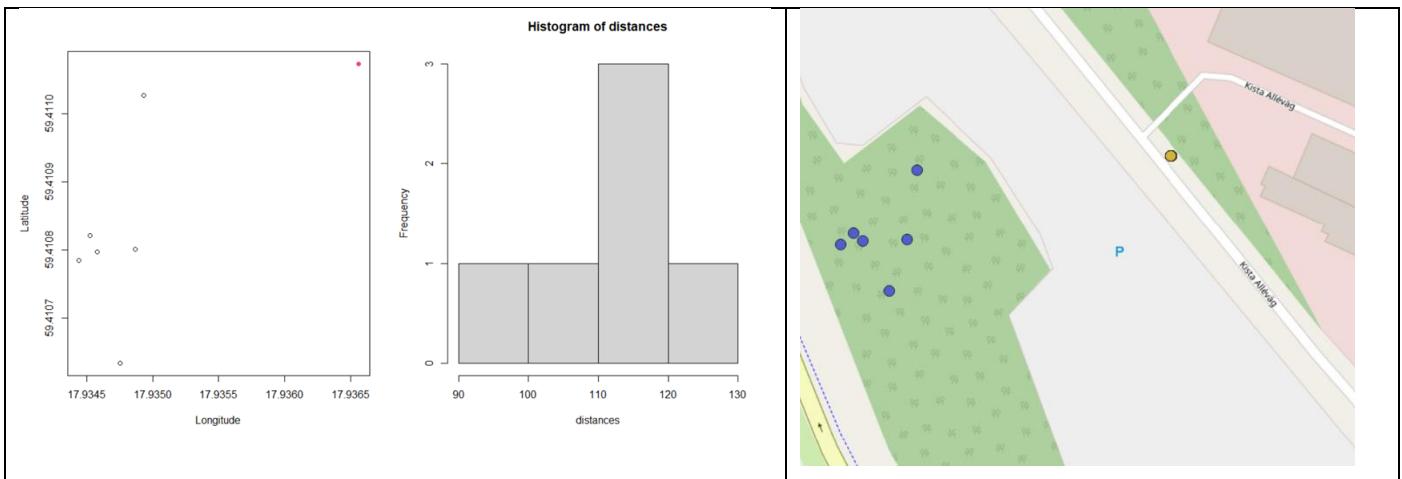
Distance	Angle deviation	Distance deviation
290.5955	-20.21915	23.54243
305.5165	-23.84762	38.46336
301.0089	-22.58895	33.95578
307.7751	-16.62729	40.72202
305.2565	-22.69694	38.20337
281.1884	-23.69002	14.13528

Site 2, test location 5, morning test campaign
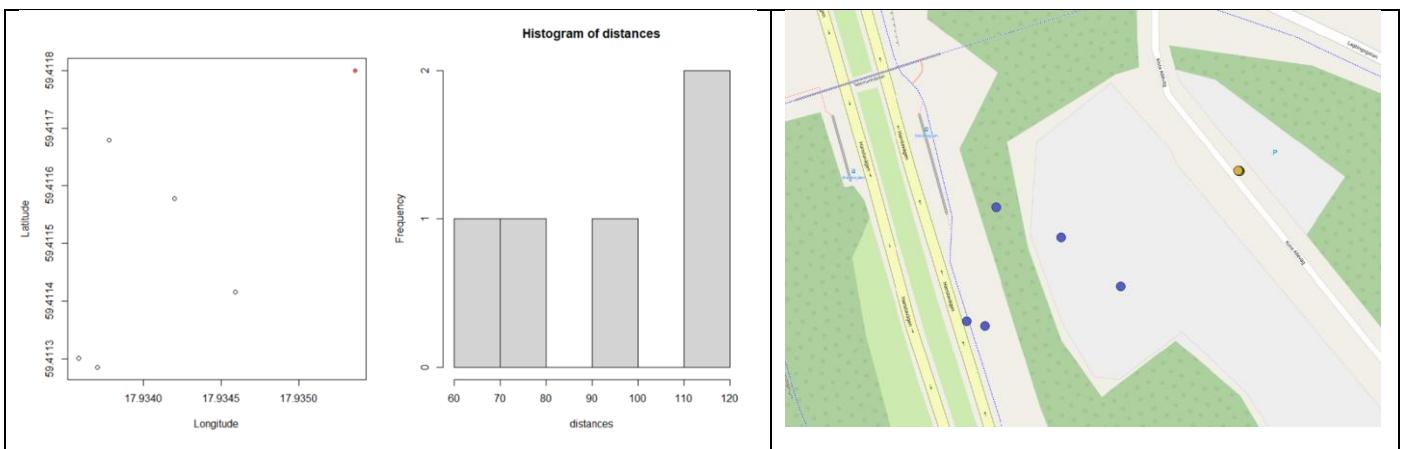
Distance	Angle deviation	Distance deviation
380.7864	-17.600922	12.409236
405.2730	-12.357089	36.895832
381.6680	-10.575523	13.290908
374.8307	-17.034816	6.453522
354.1520	-9.459483	-14.225105

*Site 2, test location 5, afternoon test campaign*
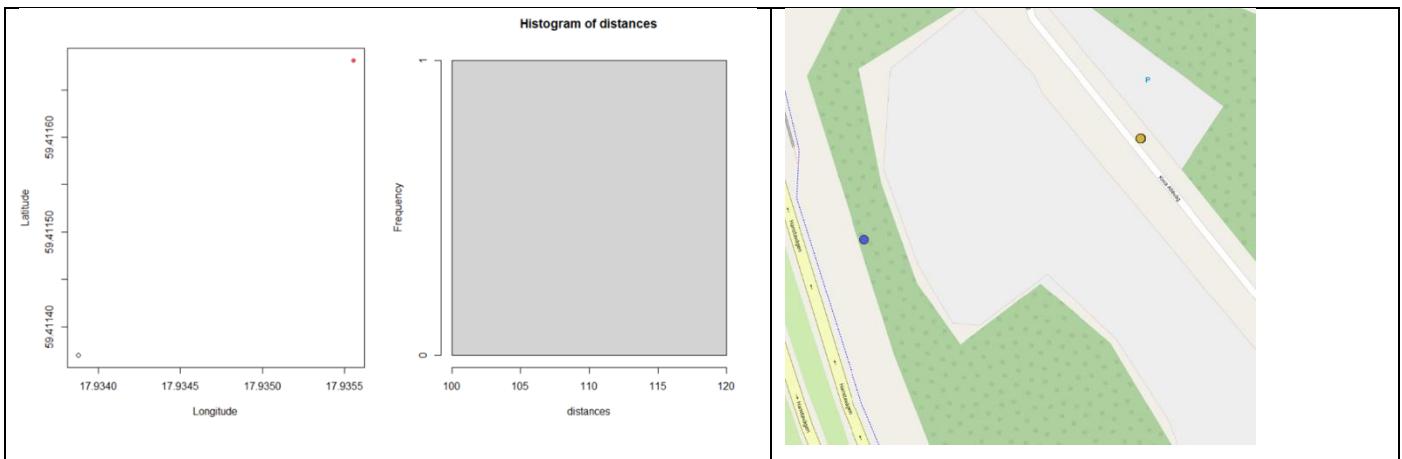
Distance	Angle deviation	Distance deviation
375.0505	-15.55704	23.28269

Site 2, test location 6, morning test campaign
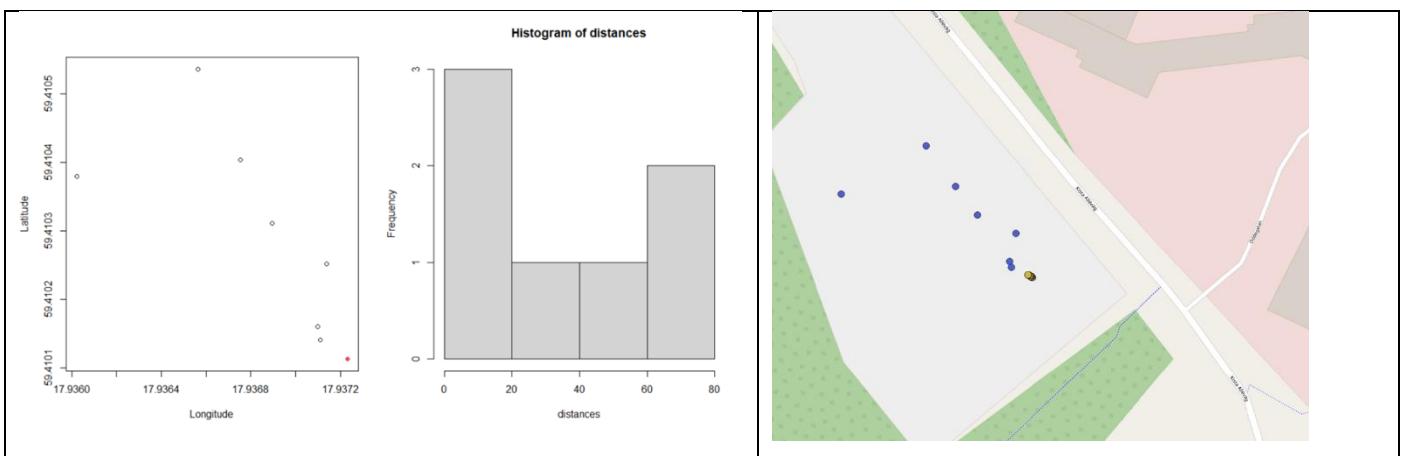
Distance	Angle deviation	Distance deviation
213.0279	-14.3188245	59.405340
212.0683	-4.7942830	58.445757
194.1012	-3.8961508	40.478584
181.3905	-3.0348220	27.767926
161.3662	-1.8025411	7.743669
159.1913	-1.8878449	5.568717
169.9339	0.2740267	16.311282

*Site 2, test location 6, afternoon test campaign*
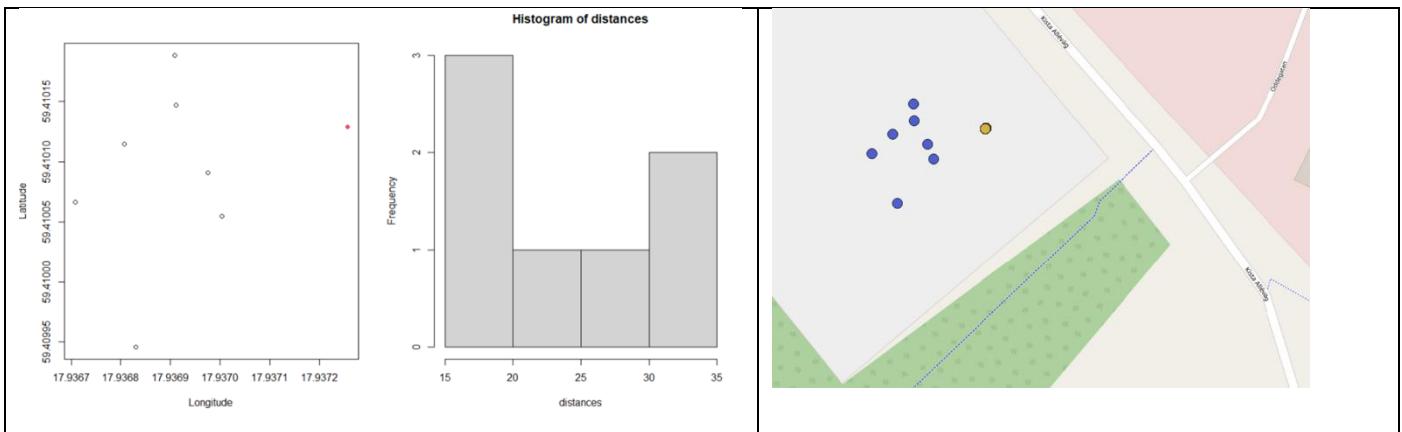
Distance	Angle deviation	Distance deviation
164.1548	-8.527305	9.391634
162.3809	-11.179511	7.617714
147.3456	-11.685316	-7.417550
168.7555	-5.444612	13.992261
164.5559	-6.112784	9.792679
153.0039	-6.120760	-1.759248
157.2988	-5.977633	2.535629

Site 2, test location 7, morning test campaign
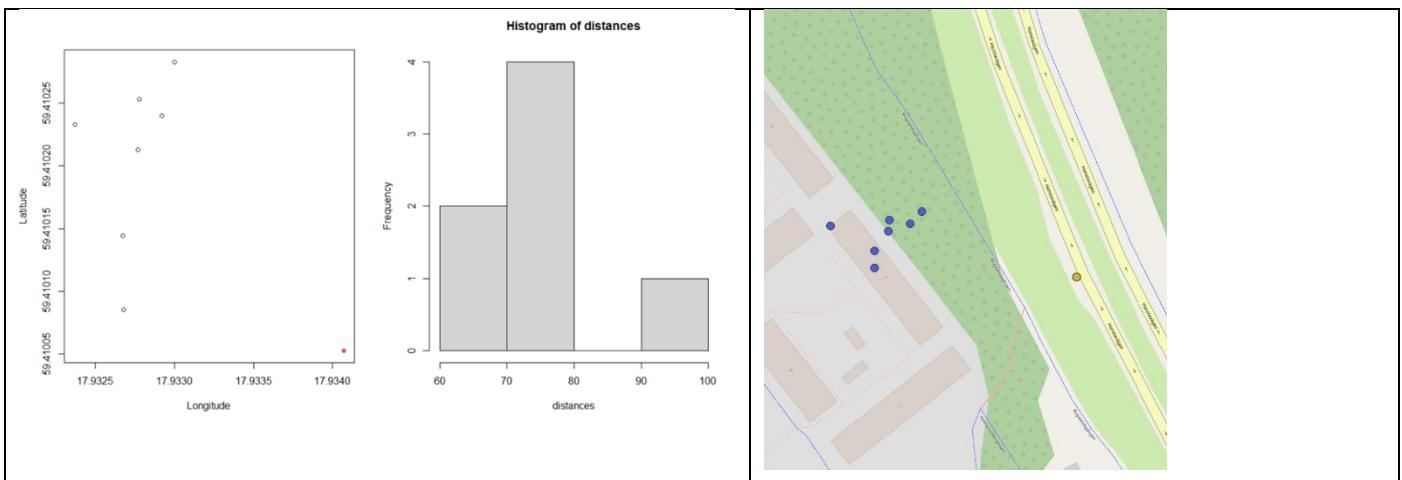
Distance	Angle deviation	Distance deviation
337.4439	-1.355638	65.21441
339.1415	-2.428356	66.91204
346.9637	-5.048724	74.73430
366.6148	-4.782912	94.38540
345.4165	-3.529460	73.18701
344.1167	-6.024635	71.88721
347.0442	-2.837569	74.81477

Site 2, test location 7, afternoon test campaign
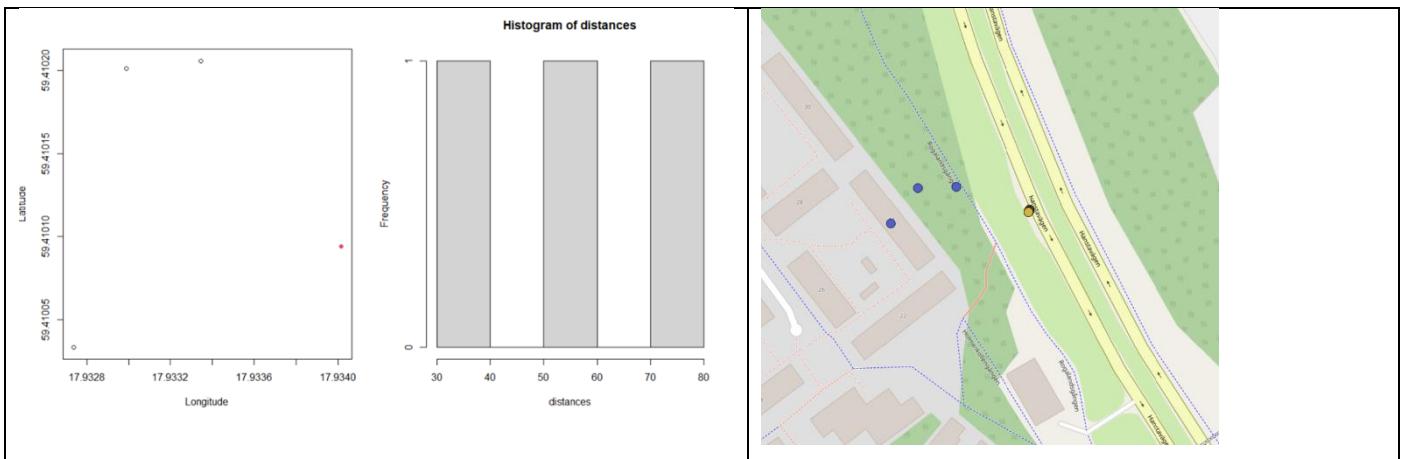
Distance	Angle deviation	Distance deviation
333.8384	-3.301017	56.63505
338.7055	-7.204877	61.50218
316.3390	-1.551264	39.13569

Site 2, test location 8, morning test campaign

Distance	Angle deviation	Distance deviation
126.37134	14.913053	67.77171
142.63711	-78.693692	84.03747
146.55018	16.121675	87.95054
123.06518	-77.269244	64.46554
119.13101	-77.981569	60.53137
124.85334	1.968591	66.25370
119.70652	-77.676310	61.10688
117.21262	-77.676311	58.61298
109.02018	15.157376	50.42055
95.00817	-75.844017	36.40853
126.50812	16.079590	67.90848
153.35607	2.600399	94.75643
108.41178	16.215236	49.81214
113.79827	15.932504	55.19863

*Site 2, test location 8, afternoon test campaign*
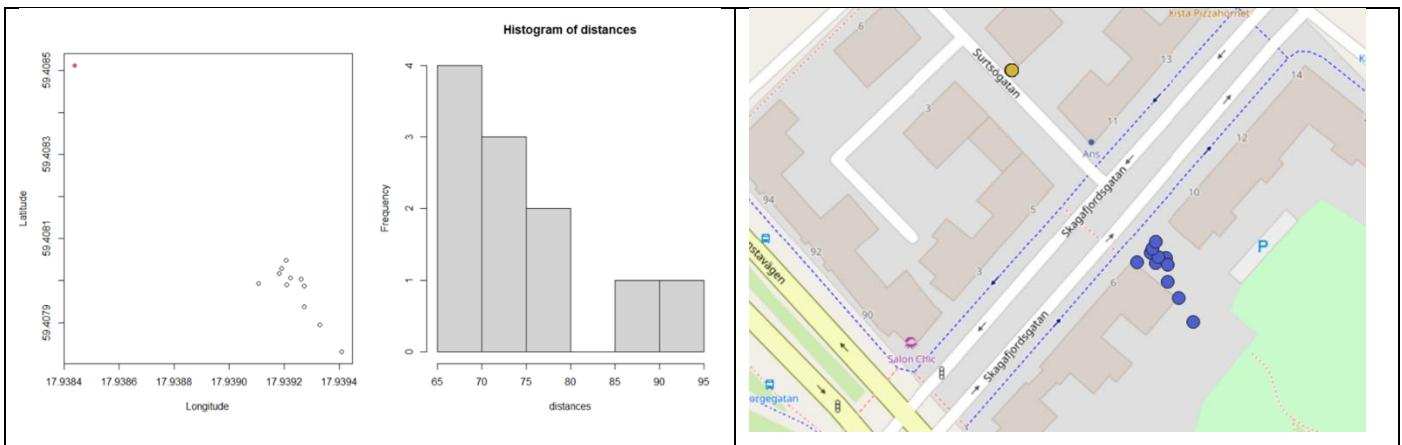
Distance	Angle deviation	Distance deviation
108.9400	-13.976079	71.67849
121.3576	-12.420289	84.09608
115.4889	-12.310831	78.22739
108.7064	-12.241665	71.44486
129.7630	-12.498525	92.50148
110.9264	-13.712808	73.66495
105.3377	-12.324268	68.07621
107.5466	-13.056284	70.28510
104.5184	-12.916022	67.25695
105.5989	-9.625539	68.33737
103.1543	-13.995441	65.89278

Site 2, test location 9, morning test campaign

Distance	Angle deviation	Distance deviation
94.24984	-6.079750	37.389963
64.35708	-5.978796	7.497209
89.41531	-2.649295	32.555437
62.45416	-2.749912	5.594290
96.11371	-2.749166	39.253836
95.41205	-4.367103	38.552176

Site 2, test location 9, afternoon test campaign
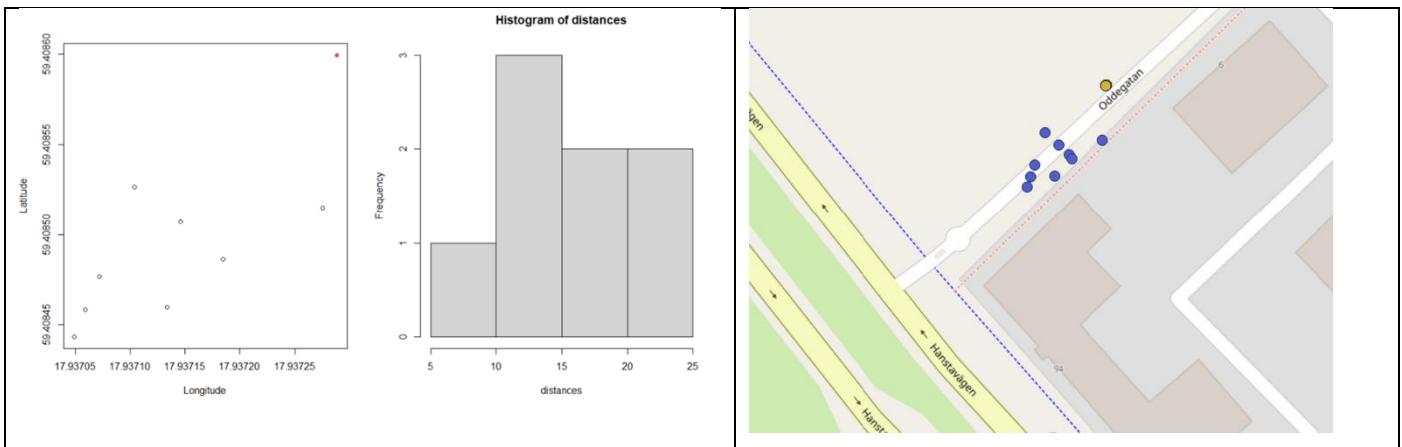
| Distance	Angle deviation	Distance deviation
72.17677	-2.250930	12.973887
74.56327	-7.903750	15.360392
78.18038	-6.290946	18.977492
70.49583	-7.201254	11.292945
64.46920	-7.298026	5.266313
79.55133	-7.095614	20.348442
76.47502	-5.279226	17.272138
71.16021	-4.672916	11.957331

Site 2, test location 10, morning test campaign
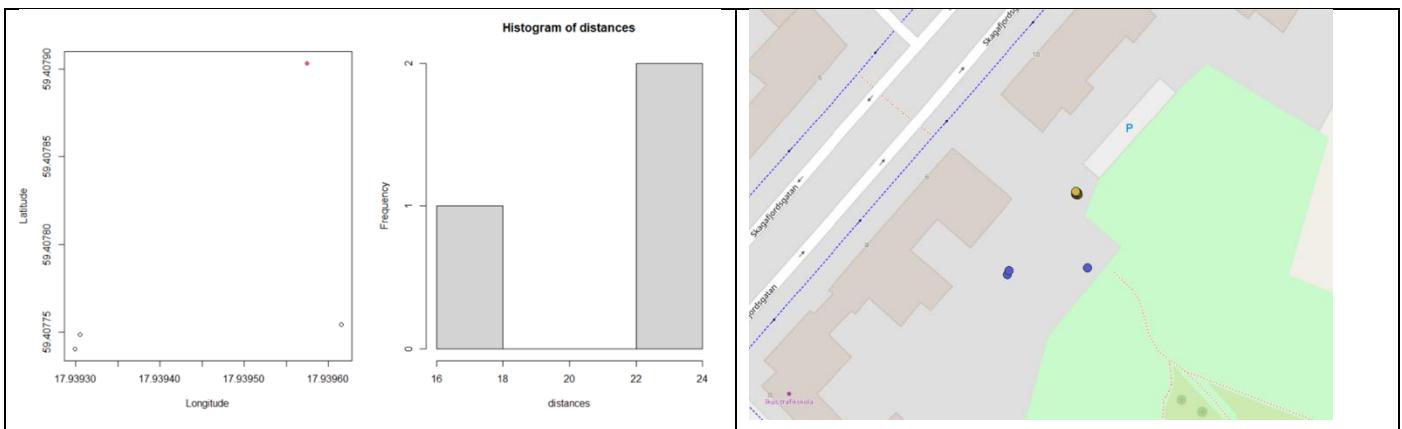
Distance	Angle deviation	Distance deviation
135.5710	9.904195	7.337556
134.9034	9.615243	6.669963
143.1677	3.200204	14.934284

Site 2, test location 10, afternoon test campaign

Distance	Angle deviation	Distance deviation
171.6107	10.623054	43.30687
150.6857	9.233497	22.38185
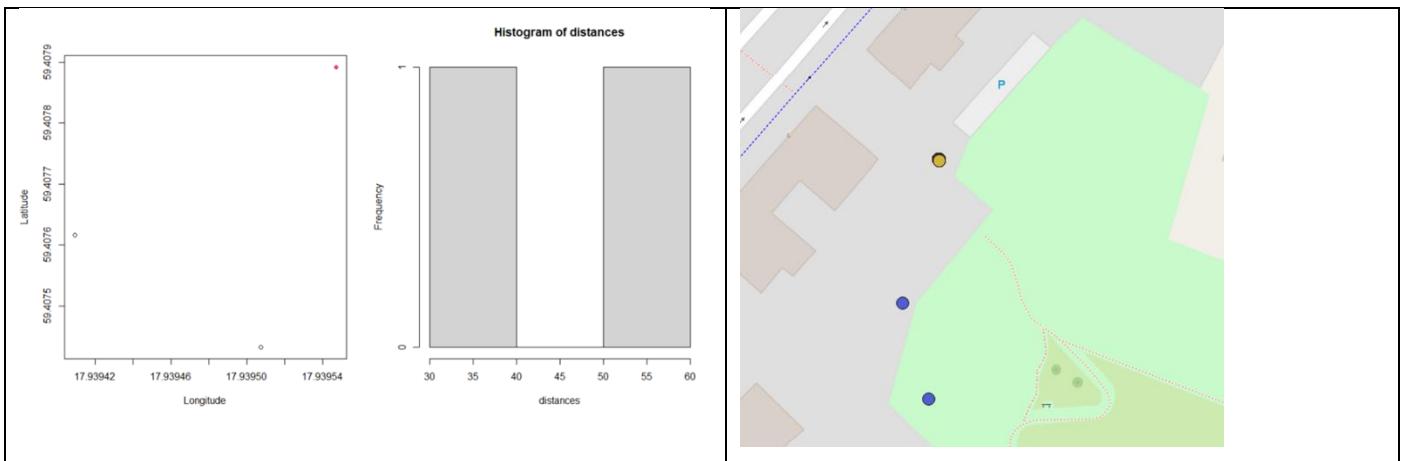
Site 2, test location 11, morning test campaign

Distance	Angle deviation	Distance deviation
201.0962	14.79414	79.50574
206.6492	15.52038	85.05874
192.0432	14.82652	70.45274
192.5099	15.72523	70.91943
191.3354	13.14673	69.74495
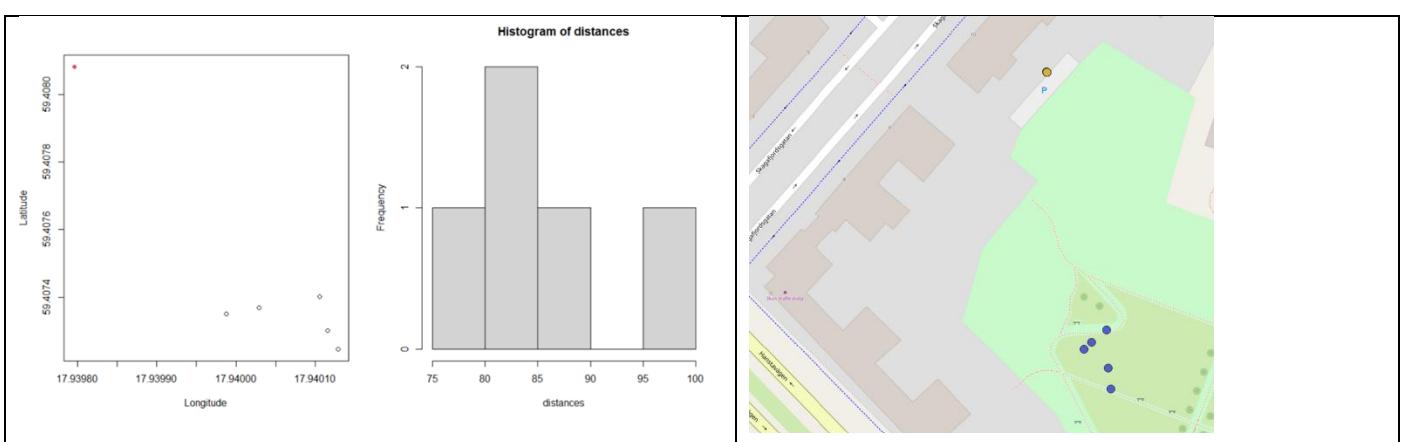
Site 2, test location 11, afternoon test campaign
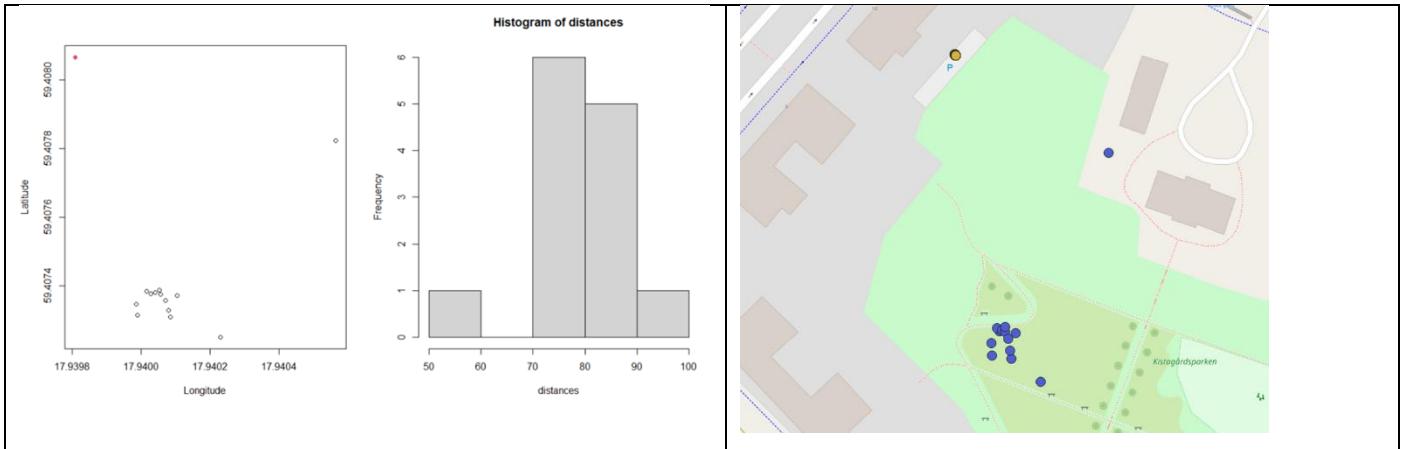
Distance	Angle deviation	Distance deviation
209.3142	13.735851	85.96393
191.1758	14.317246	67.82552
190.1278	14.370869	66.77753
191.2555	14.093434	67.90520
192.8084	15.445700	69.45813
194.0881	13.333309	70.73777
199.3676	14.706815	76.01732
197.2933	14.429230	73.94303
173.2798	-3.198534	49.92951
192.1549	13.946774	68.80462
194.3414	14.061202	70.99108
191.0233	13.770924	67.67296
195.9488	15.928361	72.59848

Overall, the 5G positioning works well, but the accuracy varies with different environments, specifically different multipath environments. At some test locations, the distance and angle error is quite small, while at other test locations, there is a bias in distance, in angle or in both distance and angle.

4.2   Drive test

A few drive tests were also conducted, where some of the tests included assumed handover between site 1 and site 2. The data did not include parameters to confirm this or localise where the handover happened. The results from these tests are shown below

Site 1 and Site 2 in use, driving in east direction (OBS: 2 min stop at red circle location)

Site 1 and Site 2 in use, driving in east direction


Site 1 and Site 2 in use, driving in west direction
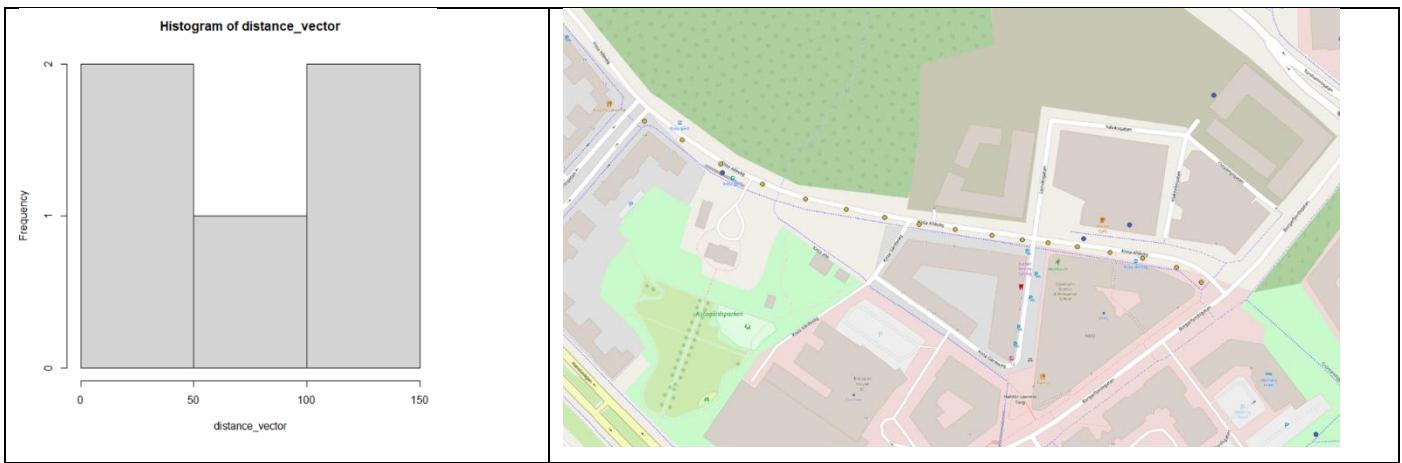
Site 1 and Site 2 in use, driving in west direction

Site 1 in use, driving in east direction

Site 1 in use, driving in west direction
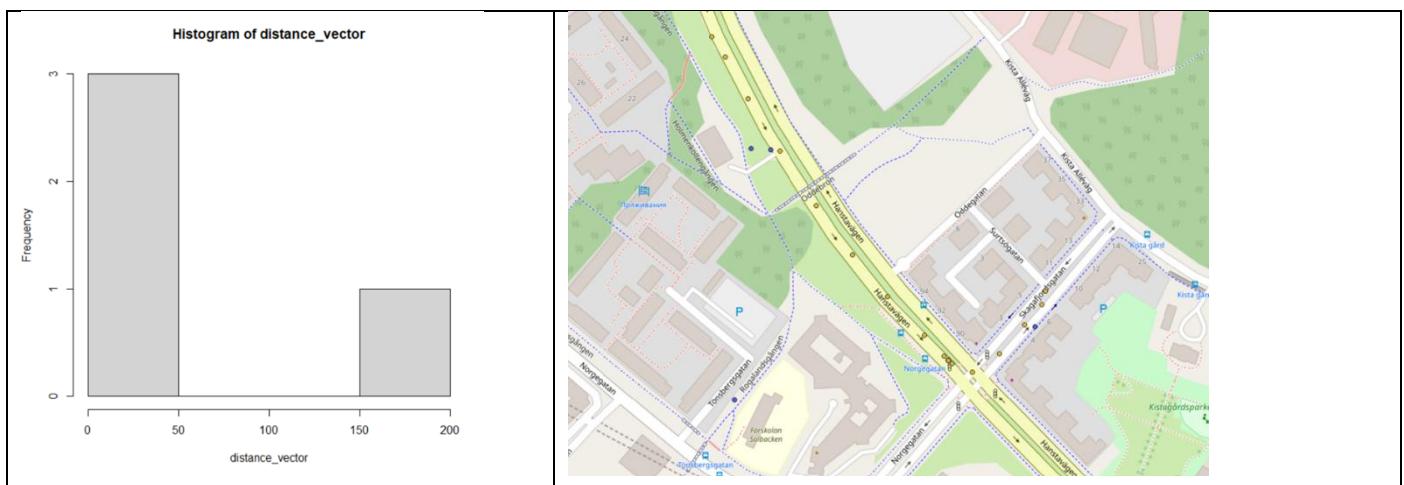
Site 2 in use, from parking and turn around

Site 1 in use, from parking and turn around
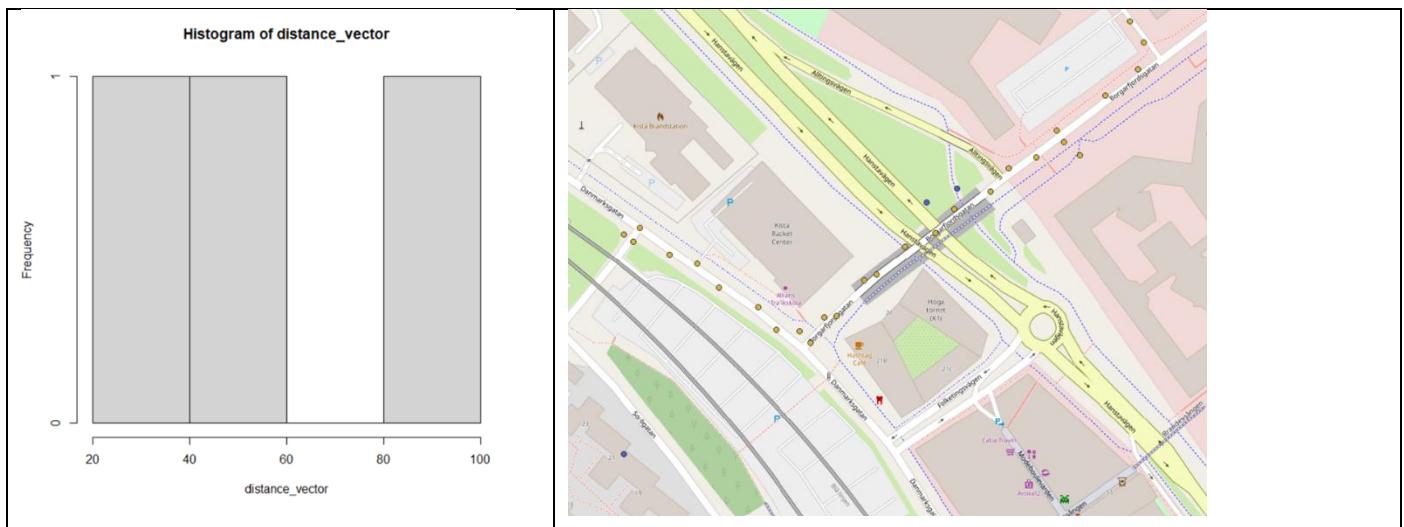
4.3   Base station coordinates

From the analyses it came clear that each base station has three antennas each covering a sector as seen in Figure 3: Telecom base stations and antennas covering a sector.
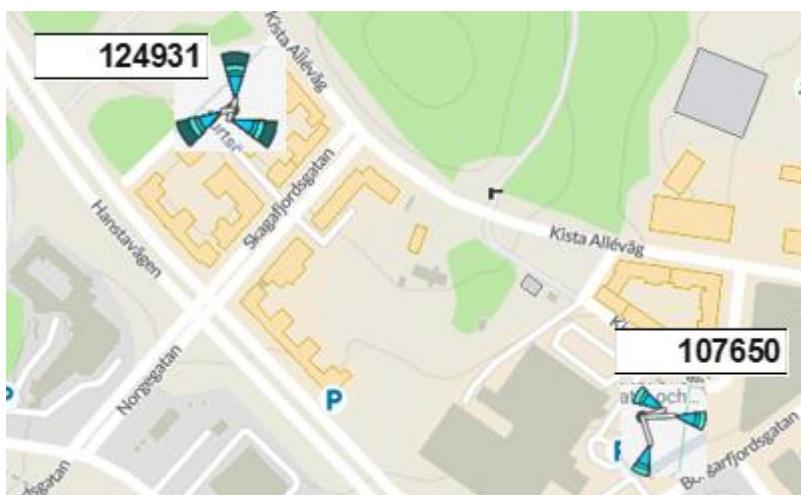

Figure 3: Telecom base stations and antennas covering a sector.

When doing the data capture one coordinate were used for each base station, and not for each antenna were the actual range and angle measurement are done. Approximate deviations from used base station coordinate to antenna coordinates are listed.

Base station	Antenna	Deviation north (m)	Deviation east (m)
107650	1	-1	28
	2	-24	8
	3	5	20
124931	1	7	2
	2	-8	-3
	3	-1	-7

These deviations will influence the 5G position coordinate that were compared to the GNSS position.

5 Summary and conclusions

Further work with 5G positioning needs to consider the coordinates of each antenna at each site. To know the correct angle each antenna is pointing are also important since position calculations are based on angle and distance measurements. Further advancements in signal processing to handle multipath effects, which affect distance and/or angle measurements, are also of concern.

6 References

[1] NorthStar by Telia and Ericsson. Assessed 14.11.2025 online.
https://www.teliacompany.com/en/offerings/northstar