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Ship Traffic Model for Container Terminals Distributions and Parameters

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Contents

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Abstract

In this report parameters for container ship traffic model are provided. This is a companion paper to "Ship Traffic Model for Container Terminals" by the same authors.

Keywords: transport modeling, container ship traffic, maritime terminal design, port capacity, data analysis.

1 Basic dataset information

The model was developed on the basis of data for maritime container terminals in Gdańsk, Long Beach, Los Angeles, Le Havre, Hamburg, Rotterdam, Shanghai, Singapore in year 2016. Basic dataset information is collected in Tab. 1. L_j are ship lengths. Values f_a denote the fraction of aperiodic (non-returning) arrivals.

Table 1: Basic dataset information

port	Gdańsk	Long Beach	Los Angeles	Le Havre
number of calls N	471	995	1308	2271
physical ships n	81	242	309	559
returning ships	57	188	238	417
No.of unique L_js	31	65	61	105
f_a[%]	5.10	5.43	5.43	6.25
port	Hamburg	Rotterdam	Shanghai	Singapore
number of calls N	3294	3998	11606	18494
physical ships n	586	311	1233	1857
returning ships	466	240	1038	1634
No.of unique L_js	101	80	148	169
f_a[%]	3.64	1.78	1.68	1.21

2 Ship Size Clustering

The ships were divided into classes (alternatively called clusters) according to the ship lengths L_j. Class i has length range $(c_{i-1}, c_i]$, where $c_0 = 0$. Values of c_i are summarized in Tab. 2. Also the total number of calls at the port for each cluster and the number of aperiodic arrivals in the cluster are given in the brackets.

In the following discussion we will refer to the clusters using a short-hand notation consisting of the initials of the port name and the cluster number starting from 1 for the shortest ship sizes. For example, RT3 is the third cluster for Rotterdam, with 532 ship calls and in this 2 aperiodic arrivals (cf. Tab.2).

Table 2: Ship size cluster intervals in meters, the total number of calls in the clusters and number of aperiodic calls.

port	Gdańsk	Long Beach	Los Angeles	Le Havre
c_1	137 (115,5)	188 (89,1)	224 (167,9)	140 (216,6)
c_2	151 (103,2)	232 (137,2)	261 (132,4)	210 (337,25)
c_3	183 (121,1)	273 (118,11)	279 (180,5)	245 (333,7)
c_4	210 (11,3)	302 (203,14)	295 (252,12)	278 (400,19)
c_5	300 (17,10)	338 (254,15)	305 (181,12)	300 (353,29)
c_6	368 (50,2)	368 (193,10)	335 (294,13)	368 (528,49)
c_7	399 (54,1)	399 (1,1)	399 (102,16)	399 (104,7)
port	Hamburg	Rotterdam	Shanghai	Singapore
c_1	141 (905,8)	102 (153,2)	101 (642,2)	192 (4552,21)
c_2	170 (956,6)	141 (2395,13)	148 (4144,11)	198 (3206,21)
c_3	213 (298,5)	152 (532,2)	183 (2263,20)	225 (2231,21)
c_4	279 (302,23)	170 (444,4)	237 (1584,30)	262 (2182,47)
c_5	338 (339,45)	223 (240,26)	297 (1800,65)	302 (3188,67)
c_6	369 (422,27)	273 (154,13)	348 (1022,53)	345 (1635,28)
c_7	400 (72,6)	305 (80,11)	367 (151,14)	400 (1500,18)

3 p_j/L_j distribution parameters

In this section parameters of the distributions fitting p_j/L_j data in the best way are given. p_j is ship processing time in hours, L_j length in meters for arrival j. `fitdistrplus` R package was used [1]. The following format of result presentation is used: first the cluster short name is given, next the name of the distribution, and the parameters of the distribution. Ship size classes short-hand notation consists of the initials of the port name and the cluster number starting from 1 for the shortest ship sizes. The distribution short names are: β - for beta distribution, exp – for exponential, γ - gamma distribution, no – for normal, ln – lognormal, ls - logistic, We – for Weibull. For more details on distribution parameters see [1].

Gdańsk:
GD1,ln, meanlog -2.2045270, sdlog 0.9806298; GD2,We, shape 1.6085042, scale 0.1253091; GD3,γ, scale 0.02542777, shape 6.13514495; GD4,β, shape1 3.796198, shape2 26.674938; GD5,ln, meanlog -2.383588, sdlog 0.612455; GD6,ln, meanlog -2.0397412 sdlog 0.4411036; GD7,We, shape 6.3138234 scale 0.2000697.

Long Beach:
LB1:ls, location 0.12513149, scale 0.05685868; LB2:We, shape 1.7859668, scale 0.2262769; LB3:ls, location 0.20100499, scale 0.04349006; LB4:ln, meanlog -2.5612589, sdlog 0.9126934; LB5:ls, location 0.23740617 scale 0.07422126; LB6:ls, location 0.23748989 scale 0.02907422; LB7: single item cluster use data directly, p_j=140h L_j=399.2m

Los Angeles:
LA1:ln, meanlog -2.0741789, sdlog 0.3958589; LA2:no, mean 0.12818969, sd 0.05853156; LA3:ls, location 0.1962775, scale 0.0541613; LA4:β,shape1 2.576578, shape2 17.518522; LA5:ls, location 0.23346274,scale 0.03294501; LA6:γ,scale 0.01622799, shape 15.51326663; LA7:ls, location 0.24577252,scale 0.03512682;

Le Havre:
LH1:ln, meanlog -2.4466108, sdlog 0.6849413; LH2:ln, meanlog -2.5382265, sdlog 0.5432081; LH3:ln, meanlog -2.6116072, sdlog 0.4608459; LH4:ls, location 0.05769683, scale 0.01408215; LH5:ln, meanlog -2.944952, sdlog 0.424198; LH6:γ, scale 0.01167714, shape 5.91481882; LH7:γ, scale 0.006849668, shape 11.434991181;

Hamburg:
HB1: We, shape 1.657545, scale 0.187926; HB2: no, mean 0.16878201, sd 0.09806034; HB3: ln, meanlog -2.4404704, sdlog 0.4536681; HB4: ln, meanlog -2.4003098, sdlog 0.3447301; HB5: ls, location 0.10171916, scale 0.01809944; HB6: ln, meanlog -2.2354715, sdlog 0.3202304; HB7: We, shape 3.8331868, scale 0.1257602;

Rotterdam:
RT1: γ, scale 0.05080236, shape 3.24384335; RT2: ln, meanlog -2.264001, sdlog 0.590673; RT3: γ, scale 0.03108345, shape 3.79563199; RT4: γ, scale 0.0293398, shape 3.8016438; RT5: β, shape1 5.195051, shape2 54.868293; RT6: ln, meanlog -2.5495952, sdlog 0.2745269; RT7: ls, location 0.08838709, scale 0.01932081;

Shanghai:
SH1: exp, rate 26.87598; SH2: ls, location 0.08019359, scale 0.01406165; SH3: ls, location 0.06672222, scale 0.01592844; SH4: ls, location 0.05303453, scale 0.01191112; SH5: ln, meanlog -2.9072884, sdlog 0.4474107; SH6: ln, meanlog -2.8731473, sdlog 0.4597978; SH7: ln, meanlog -2.4260391, sdlog 0.9032254;

Singapore:
SI1: γ, scale 0.02191416, shape 4.51531213; SI2: ln, meanlog -2.4243607, sdlog 0.4522818; SI3: γ, scale 0.009468676, shape 7.039842219; SI4: γ, scale 0.01036994, shape 5.90262497; SI5: β, shape1 6.606161, shape2 111.220183; SI6: β, shape1 7.961777, shape2 140.759075; SI7: ls, location 0.0611644, scale 0.0104015;

4 Return time ρ_j distributions summary

In this section results of fitting mixture of normal distributions into return times in certain ship size classes are given. R package `normalmixEM` was used. The results are provided in the format: ship size cluster name: ℓ - the number of components in the mixture $(\lambda_1, \mu_1, \sigma_1) \dots (\lambda_\ell, \mu_\ell, \sigma_\ell)$. Time units are days.

There are two special cases: 1. There are only 4 return periods in GD5. Hence, it was not feasible to compute the fitting mixture. Normal distribution was fit using `fitdistrplus` for completeness of presentation and compatibility with the other results, although this fit is disputable and should be considered rather speculative. 2. No results are provided for LB7 because the only ship present – "CMA CGM Benjamin Franklin" – was non-returning.

4.1 Gdańsk

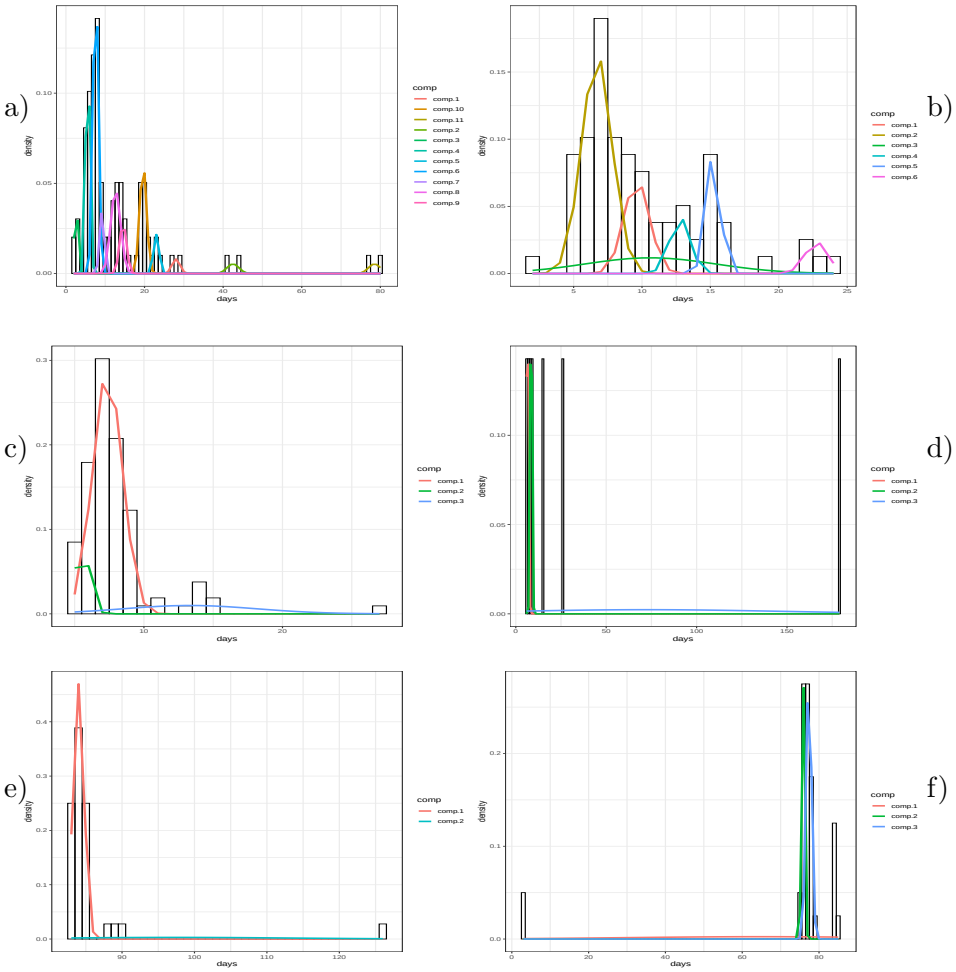

Figure 1: Return times for Gdańsk clusters, data and the fit normal mixtures. a) GD1 b) GD2 c) GD3 d) GD4 e) GD6 f) GD7.

Gdańsk
GD1: 11, (0.0505, 2.6000, 0.4899), (0.1749, 5.5587, 0.5354), (0.2817, 7.5687, 0.6658), (0.0530, 9.2066, 0.5967), (0.1460, 12.6488, 1.2607), (0.0615, 14.5319, 0.8741), (0.1325, 19.6399, 0.8703), (0.0393, 23.0155, 0.7242), (0.0202, 27.9994, 1.0012), (0.0202, 42.5000, 1.5000), (0.0202, 78.5000, 1.5000)
GD2: 6, (0.4517, 6.7046, 1.1001), (0.1632, 9.6149, 0.9298), (0.1407, 10.6054, 4.7927), (0.0779, 12.7734, 0.7398), (0.1175, 15.2180, 0.5158), (0.0489, 22.7554, 0.8292)
GD3: 3, (0.7653, 7.3724, 1.0533), (0.1153, 5.5130, 0.5313), (0.1194,13.3165, 4.8126)
GD4: 3, (0.2825, 6.5142, 0.5271), (0.2824, 8.4857, 0.5271), (0.4351,72.3471,74.7188)
GD5: 1, (1,27.0000,34.7275)
GD6: 2, (0.8819, 83.9997, 0.7490), (0.1185, 97.4030,15.9130)
GD7: 3, (0.2137, 64.7057, 34.1502), (0.2812, 75.8580, 0.3871), (0.5051, 77.3439, 0.7021)

4.2 Hamburg

Hamburg:

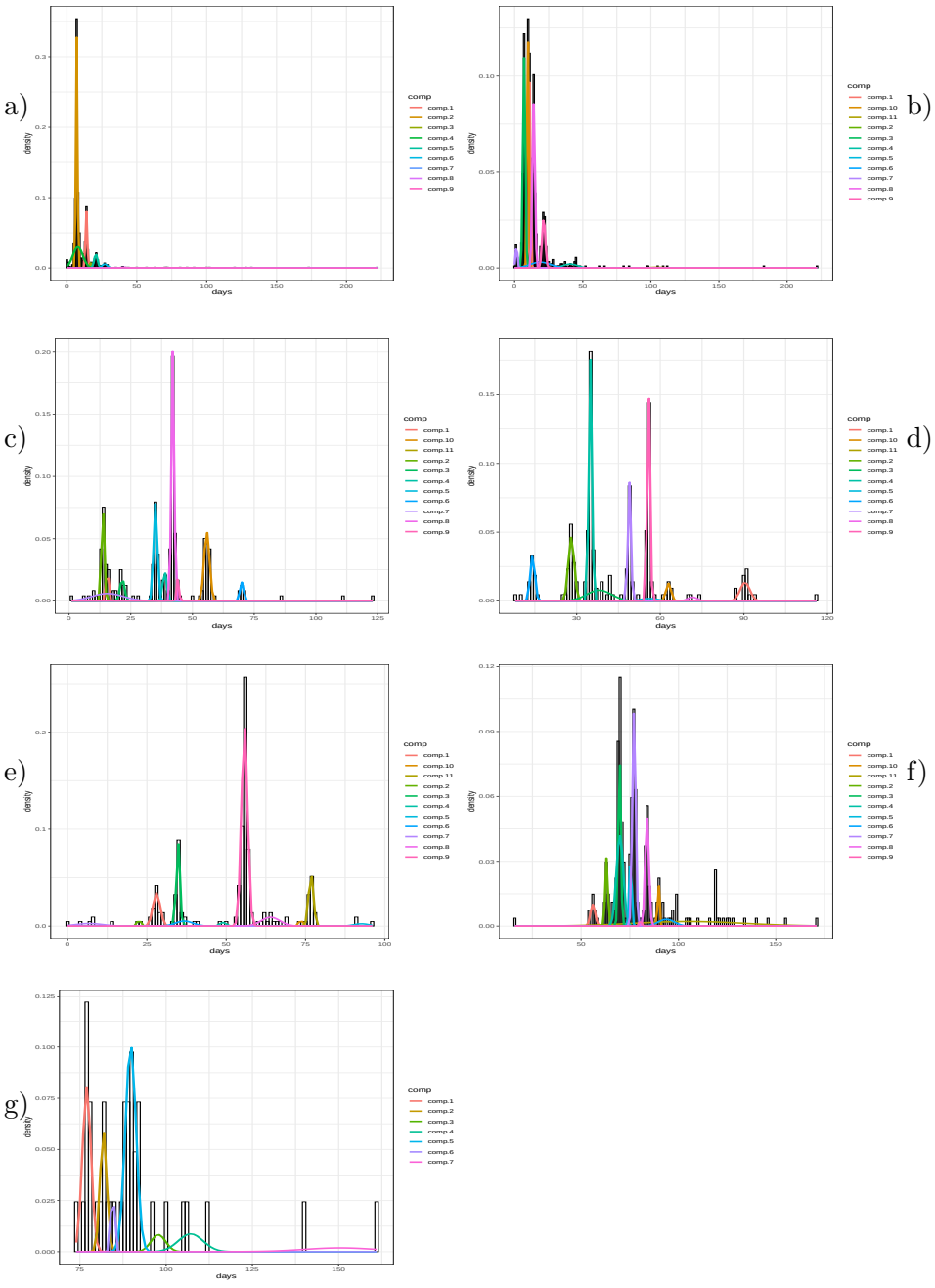

Figure 2: Return times for Hamburg clusters, data and the fit normal mixtures. a) HB1, b) HB2, c) HB3, d) HB4, e) HB6, f) HB7.

Hamburg
HB1: 9, (0.1338, 13.9463, 0.6629) (0.4781, 7.0110, 0.5821) (0.0109, 16.7469, 0.5387) (0.2652, 7.8246, 3.5046) (0.0591, 20.7478, 1.2175) (0.0249, 27.0929, 1.7919) (0.0022, 198.1930, 26.0457) (0.0048, 40.6954, 1.6975) (0.0209,

77.0945, 33.2909)
HB2: 11, (0.1519, 11.2314, 0.5786) (0.0050, 72.9334, 12.0680) (0.2460, 6.9860, 0.8959) (0.0268, 40.7911, 5.2799) (0.0022, 202.5000, 19.5009) (0.0560, 18.8840, 7.3961) (0.0203, 1.3823, 0.7127) (0.2076, 13.9854, 0.9682) (0.0758, 21.3319, 1.1658) (0.2030, 9.7024, 0.6114) (0.0053, 104.4390, 5.9359)
HB3: 11, (0.0370, 15.5176, 0.5581) (0.1119, 13.7237, 0.5692) (0.0394, 21.5831, 0.8858) (0.0474, 38.7644, 0.8111) (0.1521, 35.0377, 0.7766) (0.0284, 69.9998, 0.7520) (0.0950, 15.6744, 6.3291) (0.2923, 42.0441, 0.5804) (0.0205, 44.1639, 0.4428) (0.1527, 55.8268, 1.0967) (0.0233, 78.8618, 33.6429)
HB4: 11, (0.0583, 90.4064, 1.7251) (0.1231, 28.0825, 1.0600) (0.0864, 38.0726, 4.4006) (0.2524, 34.9258, 0.5692) (0.0141, 56.0380, 3.2205) (0.0686, 14.1930, 0.8240) (0.1179, 48.9229, 0.5397) (0.0116, 71.5730, 1.6570) (0.2029, 55.8177, 0.5169) (0.0289, 62.9764, 0.8968) (0.0358, 47.9078, 35.3381)
HB5: 11, (0.0977, 28.0399, 1.1294) (0.0093, 22.5001, 0.5000) (0.1244, 34.8233, 0.5577) (0.0093, 49.0019, 1.0032) (0.0140, 92.6667, 2.3570) (0.0349, 36.7662, 2.6745) (0.0280, 6.8373, 4.2657) (0.0674, 63.9684, 2.9195) (0.5028, 55.7818, 0.9585) (0.0094, 73.5319, 0.5407) (0.1027, 76.7290, 0.7495)
HB6: 11, (0.0307, 56.0110, 1.2115) (0.0534, 63.0652, 0.6720) (0.1348, 69.7168, 0.6585) (0.1842, 69.8943, 1.7559) (0.0506, 75.3359, 0.6348) (0.0323, 93.7556, 4.0808) (0.2138, 77.1603, 0.8522) (0.1204, 83.8510, 0.9491) (0.0037, 80.4333, 0.5943) (0.0266, 89.7338, 0.4925) (0.1494, 105.3820, 28.1660)
HB7: 7, (0.2519, 77.0001, 1.2472) (0.1431, 81.8396, 0.9661) (0.0439, 97.7382, 2.0859) (0.0784, 107.1307, 3.5942) (0.3910, 89.7361, 1.5419) (0.0429, 84.5313, 0.5143) (0.0488, 150.4860, 10.5242)

4.3 Los Angeles

Los Angeles:

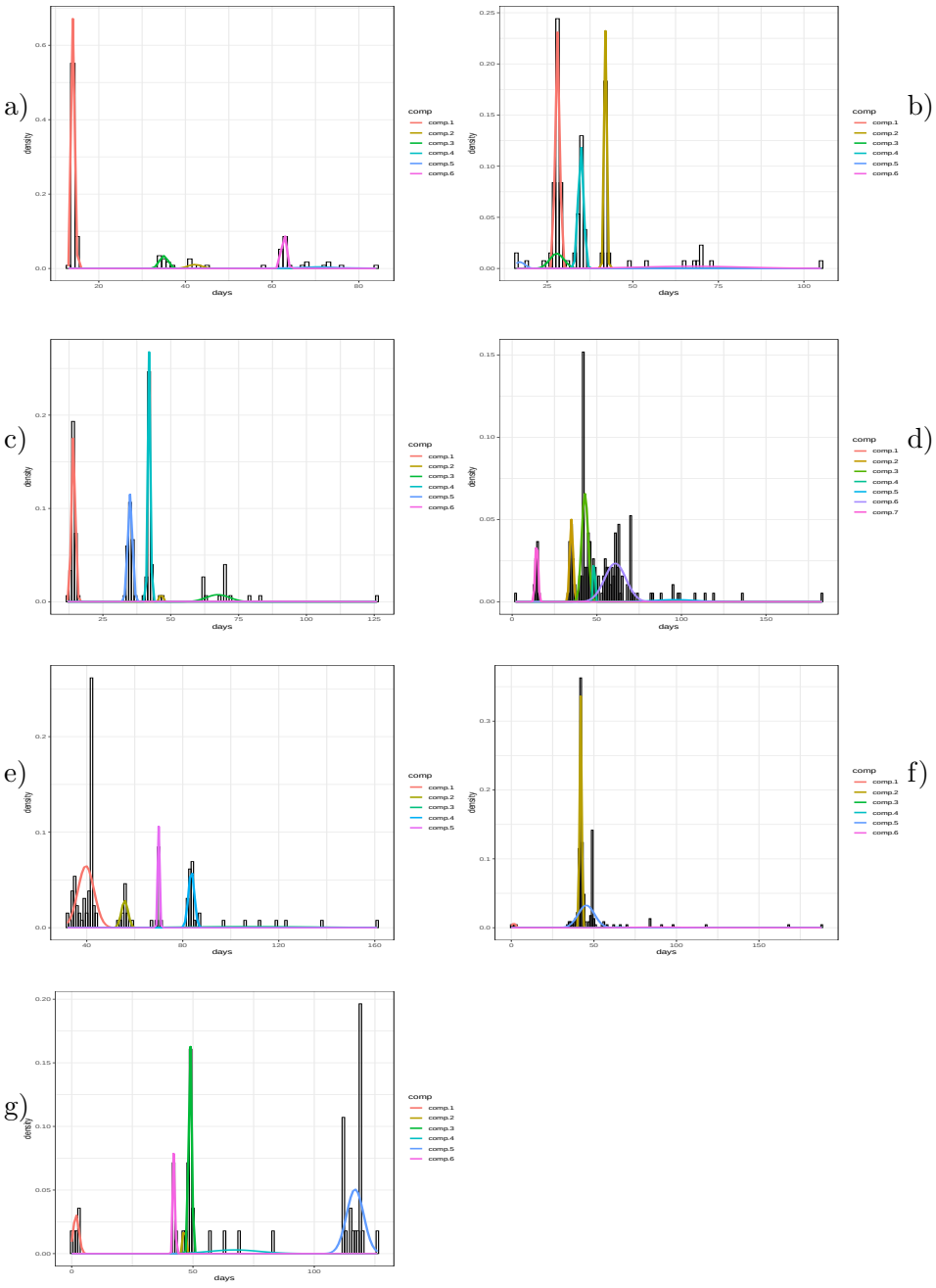

Figure 3: Return times for Los Angeles clusters, data and the fit normal mixtures. a) LA1, b) LA2, c) LA3, d) LA4, e) LA5, f) LA6, g) LA7.

Los Angeles:
LA1: 6, (0.6466, 14.1200, 0.3637) (0.0431, 42.1785, 1.6189) (0.0861, 34.9971, 0.9979) (0.0329, 70.6643, 3.0640) (0.0506, 70.2429, 8.4599) (0.1408, 62.6892, 0.5511)

LA2: 7 (0.0645, 33.8059, 0.4672) (0.0228, 16.9959, 1.4128) (0.3724, 27.9990, 0.6447) (0.1705, 35.1915, 0.4642) (0.0778, 27.7502, 1.9751) (0.2102, 41.9985, 0.3611) (0.0819, 67.2015, 15.6699)
LA3: 6 (0.3129, 14.1283, 0.7010) (0.0128, 46.4996, 0.5000) (0.0821, 67.3920, 4.3001) (0.3131, 42.0392, 0.4649) (0.2458, 35.0270, 0.8514) (0.0333, 76.0867, 30.0495)
LA4: 7 (0.0395, 91.1362, 54.0707) (0.1239, 34.9859, 0.9874) (0.3128, 42.9697, 1.8993) (0.0385, 48.3891, 0.5442) (0.0403, 96.1010, 12.6990) (0.3668, 60.8904, 6.2699) (0.0781, 14.4672, 0.8032)
LA5: 5 (0.5452, 39.6934, 3.3560) (0.0979, 55.8311, 1.3728) (0.0973, 69.9989, 0.3662) (0.1828, 83.6124, 1.2214) (0.0768, 107.5450, 28.8916)
LA6: 6 (0.0177, 1.5000, 1.1180) (0.5321, 42.0079, 0.6314) (0.0088, 178.0000, 10.0000) (0.0098, 65.1838, 3.5678) (0.4007, 45.4147, 4.9146) (0.0309, 89.1863, 15.1729)
LA7: 6 (0.0893, 1.8000, 1.1662) (0.0328, 46.4775, 0.5208) (0.2681, 48.8484, 0.6389) (0.0745, 67.1598, 10.2891) (0.4464, 116.8400, 3.5177) (0.0889, 42.1978, 0.3984)

4.4 Long Beach

Long Beach

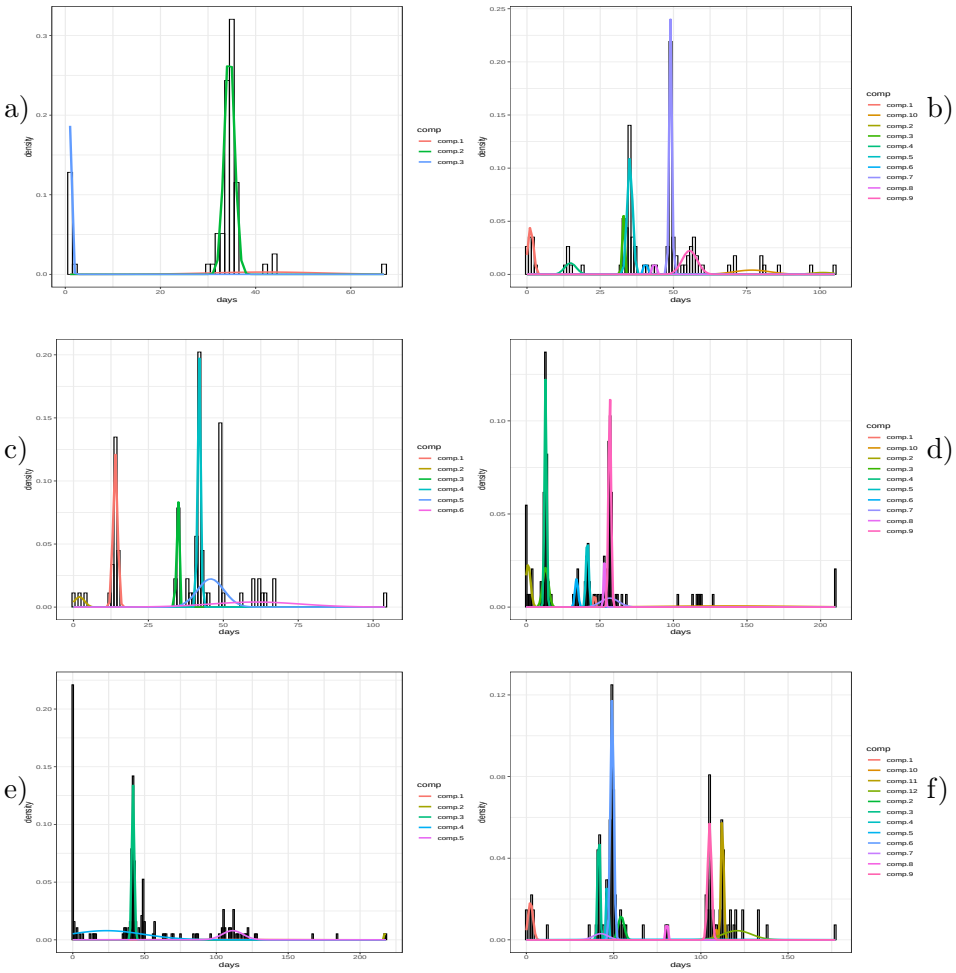

Figure 4: Return times for Long Beach clusters, data and the fit normal mixtures. a) LB1, b) LB2, c) LB3, d) LB4, e) LB5, f) LB6.

Long Beach:
LB1: 3 (0.1409, 1.0903, 0.2867) (0.7736, 34.4965, 1.0600) (0.0854, 42.2229, 11.8362)
LB2: 10 (0.1053, 1.2500, 0.9242) (0.0174, 101.0275, 4.0156) (0.0546, 32.8600, 0.3674) (0.0526, 14.8333, 1.9508) (0.2524, 35.1154, 0.9184) (0.0175, 40.5000, 0.5000) (0.2768, 49.0235, 0.4592) (0.0175, 43.5000, 0.5000) (0.1440, 55.5140, 2.5589) (0.0618, 76.8213, 6.1814)
LB3: 6 (0.2246, 13.9504, 0.7393) (0.0337, 1.9996, 1.6329) (0.0972, 34.7896, 0.4076) (0.2480, 41.9255, 0.4961) (0.2461, 45.7881, 4.3949) (0.1504, 60.7253, 15.0404)
LB4: 10 (0.0111, 46.4848, 0.4998) (0.0958, 1.2848, 1.6655) (0.1039, 13.1648, 1.9505) (0.2246, 13.1058, 0.7254) (0.0877, 41.5332, 0.9248) (0.0407, 34.1750, 1.0603) (0.0734, 56.7511, 6.0599) (0.0349, 53.1504, 0.5688) (0.2539, 56.7543, 0.8738) (0.0741, 137.5389, 48.1475)
LB5: 5 (0.0422, 105.9515, 50.0724) (0.0105, 217.5001, 0.5000) (0.2904, 41.9595, 0.8649) (0.5130, 23.4697, 25.8211) (0.1439, 111.2706, 7.2218)
LB6: 12 (0.0656, 2.3380, 1.4105) (0.0985, 41.5421, 0.6622) (0.0323, 42.6180, 4.2569) (0.0436, 46.4018, 0.4997) (0.2848, 49.1267, 0.9613) (0.0504, 54.3180, 1.7206) (0.0142, 80.5000, 0.5000) (0.0377, 87.7966, 58.7436) (0.1579, 105.0233, 1.1057) (0.0098, 108.5330, 0.5217) (0.1131, 112.3252, 0.7087) (0.0922, 120.8059, 8.2167)

4.5 Le Havre

Le Havre

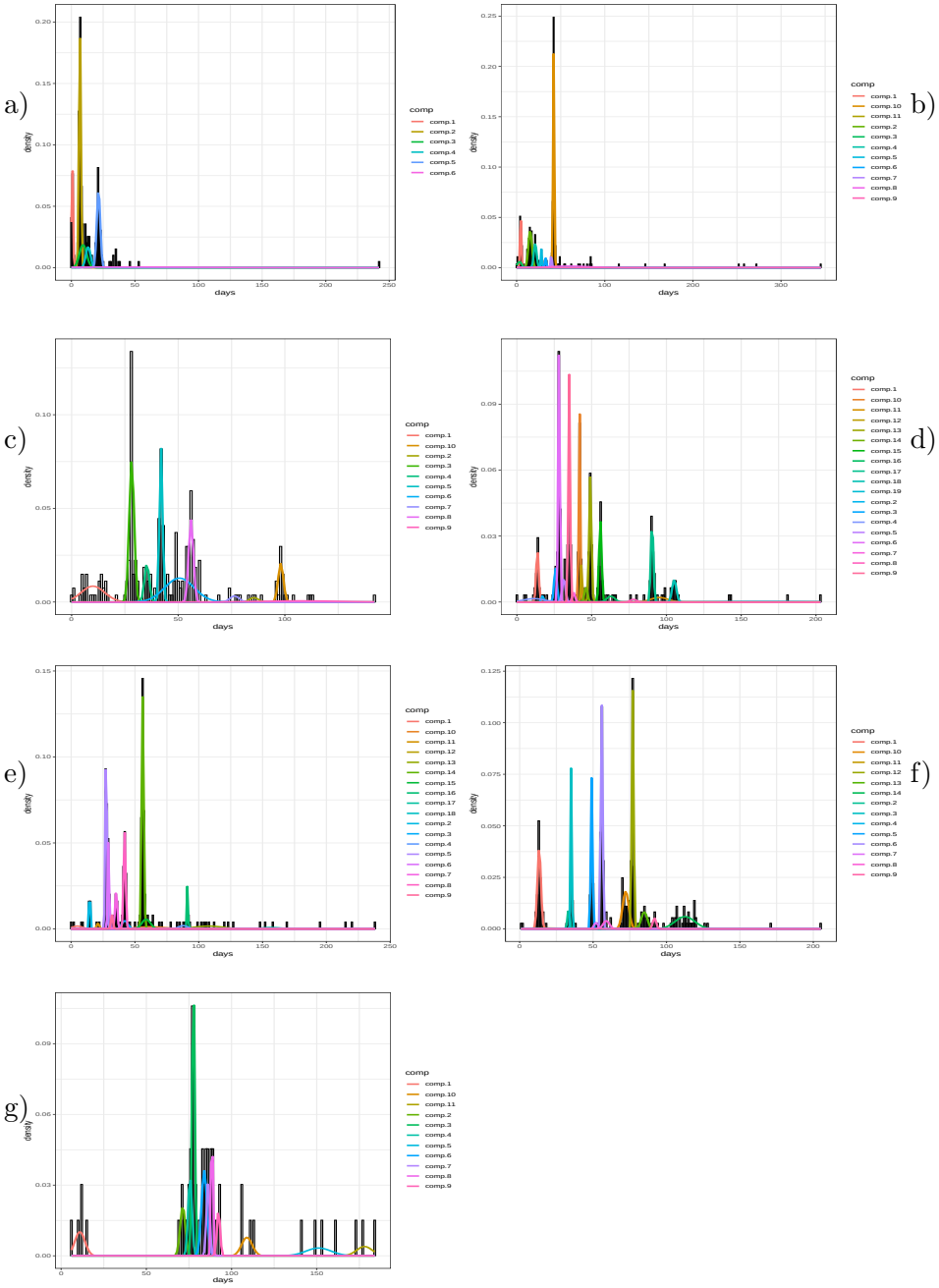

Figure 5: Return times for Le Havre clusters, data and the fit normal mixtures. a) LH1, b) LH2, c) LH3, d) LH4, e) LH5, f) LH6, g) LH7.

Le Havre:
LH1:6, (0.1151, 4.6301, 0.8343) (0.1740, 15.5915, 2.0145) (0.0685, 21.0844, 1.0550) (0.2201, 36.8575, 22.4692) (0.3928, 42.0277, 0.7392) (0.0296, 201.0784, 89.3193)

LH2: 11, (0.1017, 4.6673, 0.7990) (0.1835, 15.3701, 2.0096) (0.0363, 3.3028, 2.4242) (0.0960, 21.0775, 1.6323) (0.0273, 28.1328, 0.5773) (0.0190, 32.9941, 0.8039) (0.0217, 39.3531, 0.7300) (0.0913, 59.2163, 23.4321) (0.0147, 281.3922, 37.7351) (0.4012, 42.0738, 0.7499) (0.0073, 156.9290, 11.1290)
LH3: 10, (0.1158, 9.9860, 5.4575) (0.0118, 85.5065, 2.0357) (0.2177, 28.1665, 1.1498) (0.0574, 35.2944, 1.1335) (0.1508, 41.9474, 0.7317) (0.2190, 50.5533, 6.8542) (0.0174, 76.3862, 2.1448) (0.1197, 55.9970, 1.0894) (0.0275, 107.5454, 17.8651) (0.0630, 98.0772, 1.2232)
LH4: 19, (0.0504, 13.7125, 0.8502) (0.0054, 17.1766, 0.7615) (0.0359, 25.8101, 0.9190) (0.0268, 11.4005, 6.9706) (0.0292, 31.3876, 1.0657) (0.1722, 28.1633, 0.5894) (0.0100, 37.9291, 0.9321) (0.0063, 77.9617, 2.0447) (0.1523, 35.0051, 0.5868) (0.1066, 41.8168, 0.4591) (0.0294, 95.2060, 5.6932) (0.0229, 43.2141, 0.4999) (0.1108, 49.0712, 0.7752) (0.0171, 46.1998, 1.0419) (0.0803, 55.8154, 0.8558) (0.0175, 62.8218, 2.6557) (0.0782, 90.4310, 0.8564) (0.0357, 105.2259, 1.4236) (0.0133, 165.9805, 27.3269)
LH5: 18, (0.0164, 4.8574, 3.9447) (0.0322, 14.5008, 0.5000) (0.0287, 42.0207, 2.4154) (0.0169, 87.7792, 3.5113) (0.1718, 27.3826, 0.6065) (0.0750, 29.1995, 0.5612) (0.0478, 35.2803, 0.8714) (0.1150, 41.8780, 0.8122) (0.0157, 31.9638, 0.7835) (0.0357, 62.2495, 11.5266) (0.0081, 20.9999, 1.0000) (2.8,E-08 8,0.9138 15.9819) (0.0467, 107.7564, 11.3595) (0.2821, 56.0501, 0.8322) (0.0472, 58.7417, 3.3505) (0.0284, 91.2040, 0.4034) (0.0161, 156.7051, 7.9240) (0.0163, 216.8095, 15.5824)
LH6: 14, (0.1158, 13.2648, 1.1851) (0.0181, 33.3236, 0.7673) (0.0830, 35.1462, 0.3970) (0.0055, 187.9700, 17.0495) (0.1095, 49.0479, 0.5945) (0.1851, 55.9032, 0.6740) (0.0101, 51.9834, 1.3127) (0.0210, 59.0222, 2.1264) (0.0155, 91.8451, 1.1838) (0.0950, 72.2064, 2.0891) (0.0154, 16.6543, 14.5205) (0.1836, 77.0102, 0.6335) (0.0424, 84.8864, 2.0619) (0.0999, 112.5720, 6.7157)
LH7: 11 (0.0758, 11.0000, 2.9665) (0.0791, 71.3722, 1.5090) (0.2348, 77.6234, 0.7853) (0.0948, 75.6707, 1.1326) (0.0609, 151.1032, 7.3608) (0.1457, 83.9871, 1.6106) (0.0733, 86.2400, 0.9302) (0.0844, 88.5186, 0.5220) (0.0455, 92.3304, 0.9479) (0.0606, 109.0000, 3.0822) (0.0452, 178.0139, 4.5731)

4.6 Rotterdam

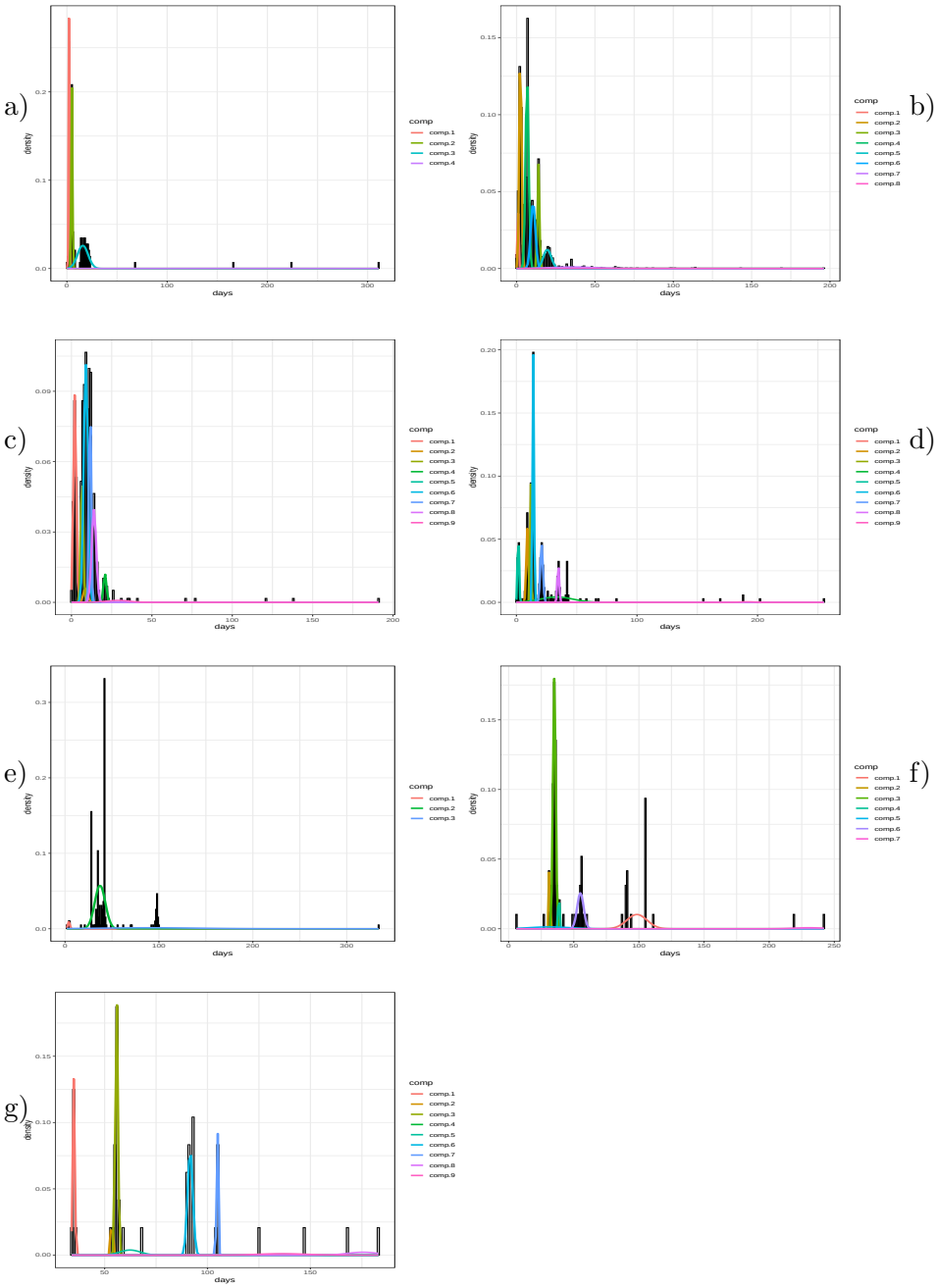

Figure 6: Return times for Rotterdam clusters, data and the fit normal mixtures. a) RT1, b) RT2, c) RT3, d) RT4, e) RT5, f) RT6, g) RT7.

Rotterdam:
RT1: 4, (0.3219, 2.1212, 0.4361) (0.3059, 4.9244, 0.5922) (0.3435, 15.8448, 5.2419) (0.0287, 186.0621, 93.0158)
RT2: 8, (0.0433, 0.8314, 0.4505) (0.2641, 2.4199, 0.6903) (0.1046, 13.9418, 0.6132) (0.3075, 6.6814, 0.9874) (0.0777, 19.5626, 2.4906) (0.1583, 10.4814, 1.4735) (0.0364, 35.5004, 14.6250) (0.0081, 92.5735, 43.3251)

RT3: 9, (0.1964, 2.0915, 0.8811) (0.0199, 8.7070, 1.3248) (0.1062, 6.5835, 0.7235) (0.0285, 20.8484, 0.9416) (0.0093, 112.9190, 48.5156) (0.3341, 8.9398, 1.3141) (0.1508, 11.5555, 0.6223) (0.1401, 13.9652, 1.4132) (0.0147, 28.9163, 6.9944)
RT4: 9, (0.0158, 158.1524, 65.6611) (0.1242, 9.0092, 0.8485) (0.1379, 11.7955, 0.5474) (0.1429, 33.2861, 13.4660) (0.0877, 1.5672, 0.6069) (0.3030, 13.9432, 0.6140) (0.1263, 20.8740, 1.1102) (0.0556, 34.7185, 0.7639) (0.0065, 191.6630, 6.3088)
RT5: 3, (0.0241, 4.0535, 1.0552) (0.8101, 37.2689, 5.6303) (0.1657, 90.0074, 50.8505)
RT6: 7, (0.1979, 98.4743, 7.7144) (0.0566, 31.2897, 0.4555) (0.4799, 35.0725, 1.0630) (0.0352, 38.5434, 0.5123) (0.0508, 31.4855, 15.2629) (0.1588, 55.0800, 2.4582) (0.0208, 230.5000, 11.5000)
RT7: 9 (0.1667, 35.0000, 0.5000) (0.0375, 53.4756, 0.5204) (0.3095, 55.8453, 0.6352) (0.0095, 136.3048, 11.6007) (0.0488, 62.3425, 5.0421) (0.2500, 91.5833, 1.2555) (0.1041, 104.8003, 0.3998) (0.0412, 175.5725, 7.5442) (0.0327, 136.3576, 11.6067)

4.7 Shanghai

Shanghai:

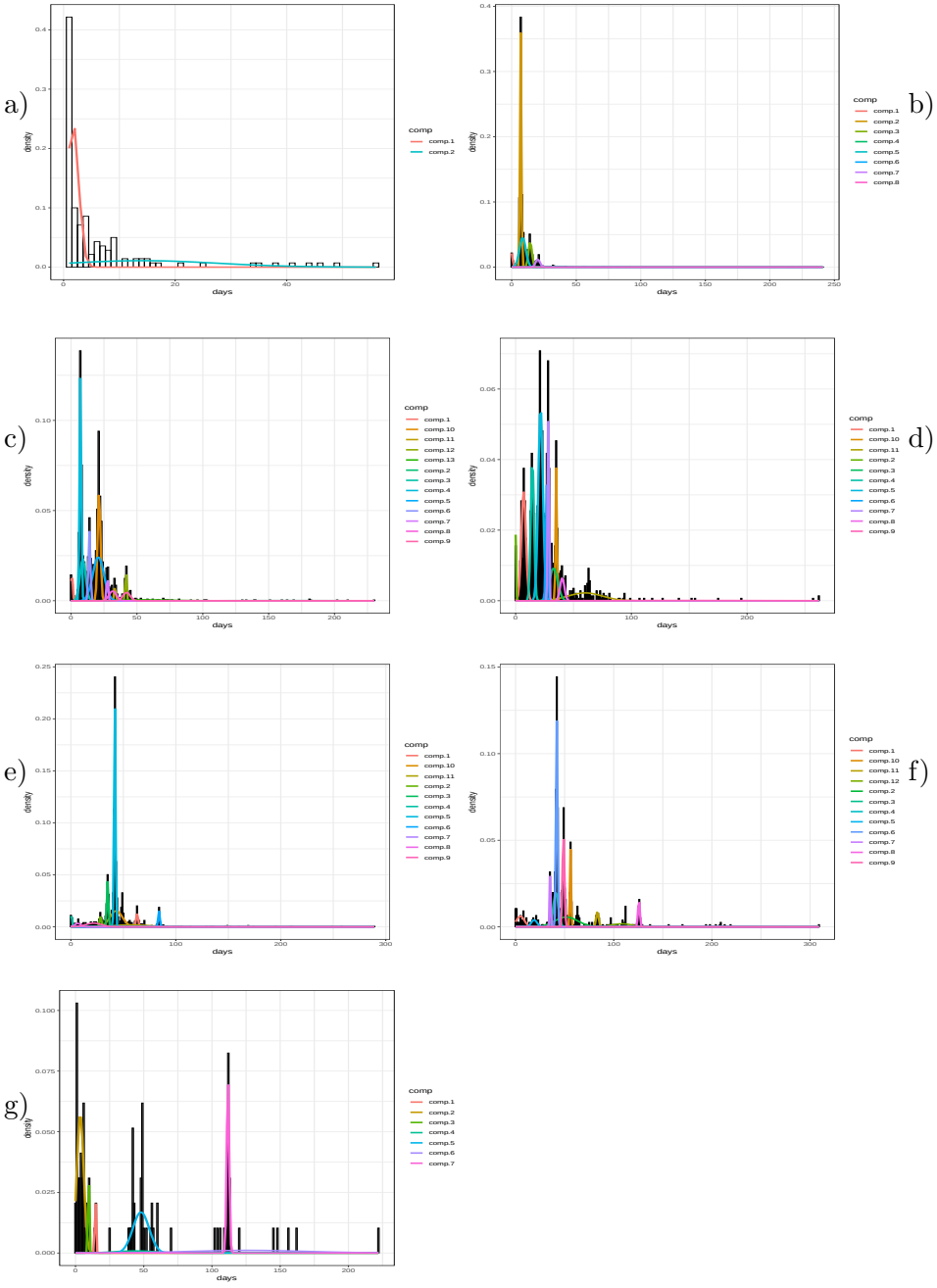

Figure 7: Return times for Shanghai clusters, data and the fit normal mixtures. a) SH1, b) SH2, c) SH3, d) SH4, e) SH5, f) SH6, g) SH7.

Shanghai:
SH1: 2, (0.6331, 1.6613, 1.0242) (0.3669, 14.1485, 13.4295)

SH2: 8, (0.0314, 0.3160, 0.4766) (0.4881, 6.9727, 0.5419) (0.1302, 14.3095, 1.3639) (0.0141, 34.2408, 5.5631) (0.2757, 8.4291, 2.4241) (0.0068, 62.7254, 29.4980) (0.0517, 20.2059, 1.7175) (0.0020, 219.8740, 12.0298)
SH3: 13, (0.0261, 0.5523, 0.6736) (0.0074, 162.5770, 35.1967) (0.1235, 8.9003, 2.1304) (0.2087, 7.1334, 0.6618) (0.2537, 20.7196, 4.1843) (0.0694, 13.9479, 0.7193) (0.0211, 27.5848, 0.6058) (0.0370, 31.6271, 2.7398) (0.0310, 42.1329, 2.6936) (0.1634, 21.2666, 1.0828) (0.0119, 33.3854, 0.5469) (0.0231, 41.6914, 0.5538) (0.0238, 55.8583, 20.6266)
SH4: 11, (0.0183, 0.1496, 0.3567) (0.1515, 6.8757, 1.9607) (0.1386, 14.4486, 1.3933) (0.2740, 21.5482, 2.0014) (0.0694, 26.9064, 0.8405) (0.0848, 28.3127, 0.5740) (0.0830, 32.7388, 3.5934) (0.0572, 35.1291, 0.5930) (0.0305, 40.2626, 1.8842) (0.0815, 60.0605, 14.7204) (0.0113, 145.2768, 68.3605)
SH5: 11, (0.0323, 63.0913, 1.0583) (0.0226, 28.2338, 0.9268) (0.0837, 35.0308, 0.7697) (0.0193, 0.4434, 0.5042) (0.3840, 41.8215, 0.7085) (0.0299, 83.9540, 0.7978) (0.0201, 144.7515, 60.2833) (0.0242, 6.4842, 2.8809) (0.0680, 21.6077, 7.5080) (0.2289, 43.1780, 5.9113) (0.0871, 57.0652, 17.9010)
SH6: 12, (0.0624, 4.9412, 4.0414) (0.1667, 51.6253, 11.7386) (0.1244, 41.1000, 2.5188) (0.0163, 198.8757, 44.0337) (0.0299, 18.9097, 2.9557) (0.2408, 41.9505, 0.8072) (0.0441, 35.2652, 0.5337) (0.0368, 125.6669, 0.9901) (0.1351, 48.7999, 1.0504) (0.0676, 55.9205, 0.5994) (0.0286, 83.3486, 1.3103) (0.0472, 108.2039, 10.6441)
SH7: 7, (0.0305, 14.6687, 0.4707) (0.3566, 3.4906, 2.4873) (0.0447, 9.6400, 0.4917) (0.0328, 43.3592, 15.1970) (0.2515, 47.9929, 5.9499) (0.1182, 126.8345, 43.5734) (0.1658, 111.7361, 0.9159)

4.8 Singapore

Singapore:

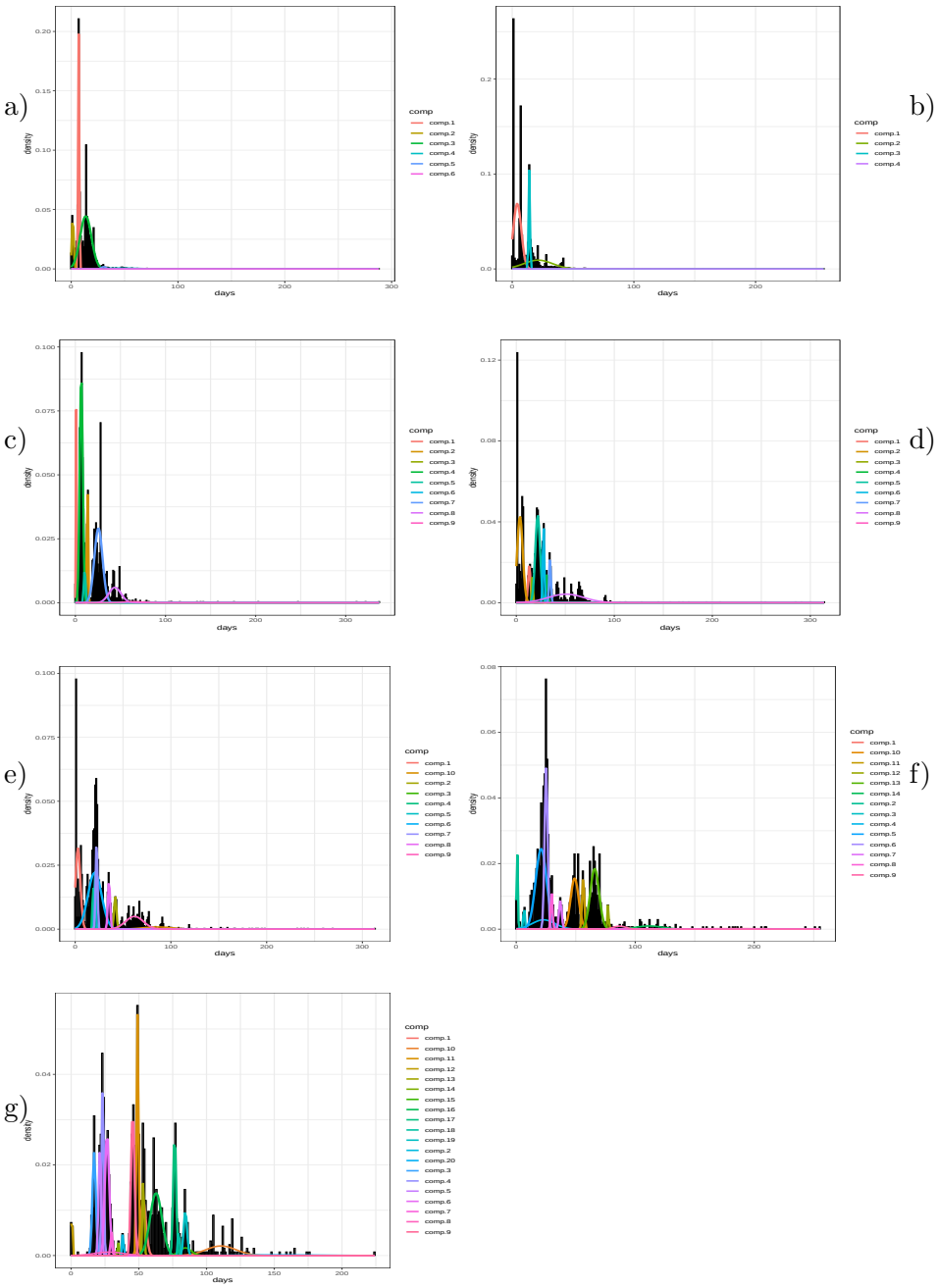

Figure 8: Return times for Singapore clusters, data and the fit normal mixtures. a) SI1, b) SI2, c) SI3, d) SI4, e) SI5, f) SI6, g) SI7.

Singapore:
SI1: 6, (0.0953, 1.4373, 0.8761) (0.2666, 7.0003, 0.5380) (0.5906, 13.6287, 5.2837) (0.0095, 30.3870, 2.0189) (0.0294, 45.9045, 16.0767) (0.0088, 127.48, 66.4079)

SI2: 4, (0.5687, 4.1500, 3.2873) (0.1437, 14.0320, 0.5509) (0.2700, 21.3500, 11.6884) (0.0177, 74.3963, 52.1076)
SI3: 9, (0.0651, 0.8983, 0.3278) (0.0762, 13.6129, 0.5728) (0.0015, 323.6830, 10.2724) (0.3759, 6.5573, 1.6881) (0.0319, 10.3550, 1.0120) (0.0073, 125.9380, 54.5762) (0.3296, 25.6219, 4.4997) (0.1016, 43.8550, 6.7602) (0.0110, 64.6700, 11.0786)
SI4: 9, (0.0554, 13.2004, 1.2091) (0.3031, 3.7077, 2.8289) (0.0203, 16.3365, 0.5390) (0.0319, 31.1633, 0.9176) (0.2646, 21.8144, 2.4491) (0.0742, 27.7924, 0.7819) (0.0473, 34.3067, 0.8375) (0.1936, 50.7104, 18.2230) (0.0095, 185.5300, 78.8977)
SI5: 10, (0.2003, 2.9135, 2.5237) (0.0394, 41.8823, 1.2544) (0.0126, 162.1931, 62.0449) (0.0287, 18.7046, 0.6496) (0.0421, 20.7642, 0.7104) (0.3930, 20.4949, 7.0738) (0.0816, 22.3735, 0.9400) (0.0535, 35.3515, 1.1482) (0.1159, 61.9371, 9.3212) (0.0327, 85.9281, 15.4469)
SI6: 14, (0.0146, 183.9882, 38.6463) (0.0335, 0.7790, 0.5456) (0.0103, 6.5736, 0.5106) (0.0672, 22.9341, 9.4418) (0.2835, 20.9381, 4.6111) (0.1574, 25.1138, 1.2747) (0.0245, 37.0717, 1.1476) (0.0210, 29.7434, 0.7374) (0.0121, 86.8867, 5.2747) (0.1304, 49.0826, 3.3492) (0.0373, 56.2973, 0.9421) (0.0096, 77.2687, 0.4433) (0.1712, 65.8876, 3.6990) (0.0274, 111.8411, 11.3312)
SI7: 20 (0.1502, 62.6794, 4.3268) (0.1068, 26.5205, 1.5808) (0.1001, 45.5012, 1.2485) (0.0981, 49.0512, 0.7341) (0.0726, 23.3393, 0.7232) (0.0711, 76.4646, 1.0546) (0.0699, 16.9603, 1.2271) (0.0620, 53.2550, 2.0498) (0.0590, 21.3225, 0.9806) (0.0587, 110.6465, 11.0962) (0.0304, 84.3472, 1.2408) (0.0288, 53.3357, 0.6254) (0.0200, 28.0137, 10.6619) (0.0184, 84.3330, 4.3330) (0.0138, 0.4702, 0.4991) (0.0106, 153.5931, 30.6550) (0.0101, 29.9137, 0.7820) (0.0089, 79.4122, 0.5620) (0.0067, 38.2505, 0.5259) (0.0039, 34.8108, 0.5357)

5 Periodic arrivals

In this section we provide histograms of periodic returning ships arrival collected over all classes. These can be used to generate the first arrival of a returning ship. Arrivals frequencies are shown as fractions of all periodic arrivals. Ship size classes are not distinguished. In Fig.9 coefficients of variation of ships weekly and daily arrivals are shown vs total number of arrivals in a port. It can be seen that variability of arrivals decreases with the number of served calls.

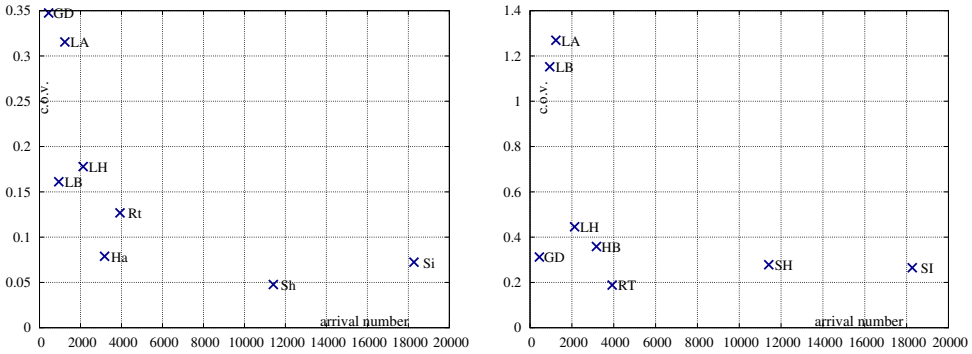

Figure 9: Coefficients of variation for periodic arrivals frequencies a) over days of week, b) over hours of day.

5.1 Histograms for Days of Week periodic arrivals

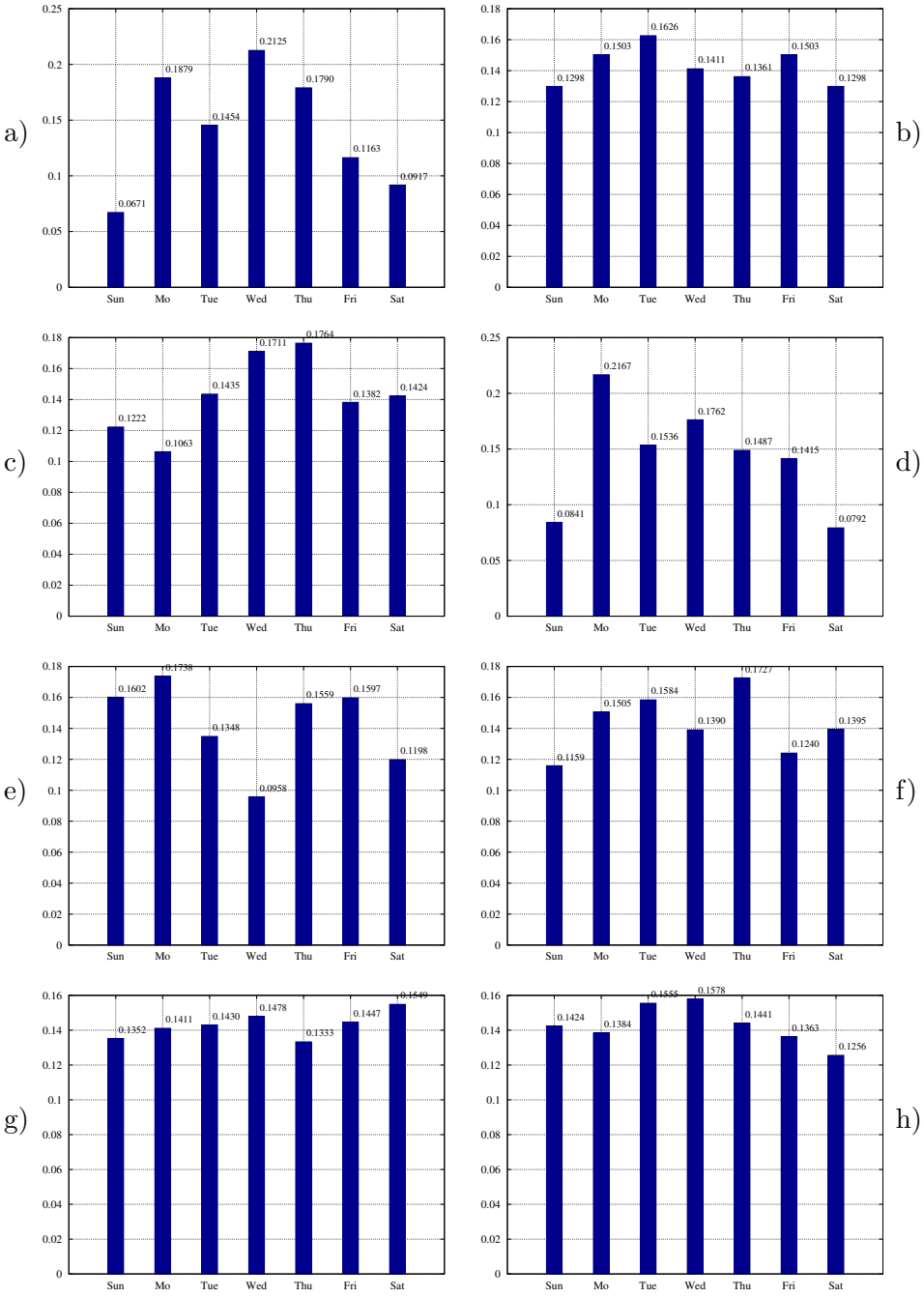

Figure 10: Histograms of periodic ship arrivals frequencies (relative to all periodic arrivals) over days of week. All classes together. a) Gdańsk, b) Hamburg c) Long Beach, d) Los Angeles, e) Le Havre. f) Rotterdam g) Shanghai h) Singapore.

5.2 Histograms for Hours of Day periodic arrivals

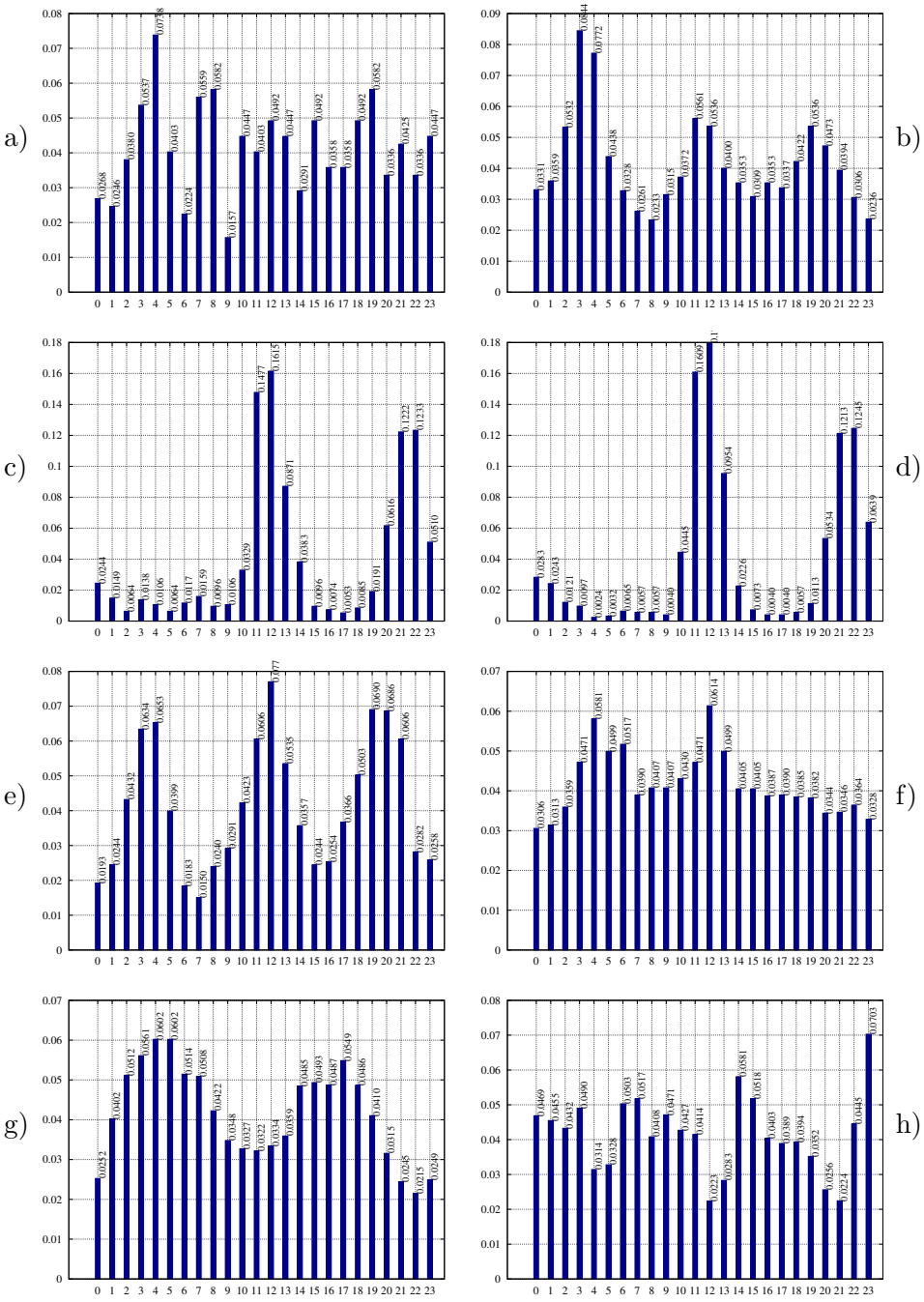

Figure 11: Histograms of periodic ship arrivals frequencies (relative to all periodic arrivals) over hours of day. All classes together. a) Gdańsk, b) Hamburg c) Long Beach, d) Los Angeles, e) Le Havre. f) Rotterdam g) Shanghai h) Singapore.

6 Aperiodic ready times

6.1 Weeks of the year

In this section coefficients $a_4, \ldots, a_0$ of the 4th degree polynomials $f(w) = a_4w^4 + a_3w^3 + a_2w^2 + a_1w^1 + a_0$, where w is the number of a week in year, fit into relative weekly arrival frequencies of aperiodic ships are provided. Ship size classes are not distinguished, i.e. all classes were collected in the input data. These polynomials can be used as a model of probability density of aperiodic arrivals in certain week w. The coefficients are provided in the order $(a_0, a_1, a_2, a_3, a_4)$. Results for the sum of all port weekly aperiodic ships arrival frequencies are also provided. Coefficients of lower degree polynomials are also provided.

degree 4:
Gdańsk: (3.539E-02, -3.249E-03, 2.313E-04, -6.265E-06, 5.474E-08)
Hamburg: (7.484E-02, -9.514E-03, 5.526E-04, -1.298E-05, 1.029E-07)
Long Beach: (8.246E-03, 4.799E-03, -4.873E-04, 1.584E-05, -1.582E-07)
Los Angeles: (1.237E-02, 3.044E-03, -2.483E-04, 6.803E-06, -6.012E-08)
Le Havre: (5.085E-02, -1.837E-03, -4.182E-05, 2.442E-06, -2.206E-08)
Rotterdam: (5.488E-02, -3.038E-03, -1.281E-05, 2.973E-06, -3.418E-08)
Shanghai: (5.128E-02, -6.546E-03, 4.039E-04, -1.018E-05, 8.994E-08)
Singapore: (6.248E-02, -8.546E-03, 5.044E-04, -1.277E-05, 1.178E-07)
Sum of all ports: (4.379E-02, -3.111E-03, 1.127E-04, -1.767E-06, 1.135E-08)

degree 3:
Gdańsk: (2.798E-02, -7.153E-04, 2.474E-05, -3.527E-07)
Hamburg: (6.090E-02, -4.752E-03, 1.644E-04, -1.864E-06)
Long Beach: (2.967E-02, -2.523E-03, 1.097E-04, -1.251E-06)
Los Angeles: (2.051E-02, 2.619E-04, -2.150E-05, 3.103E-07)
Le Havre: (5.384E-02, -2.858E-03, 4.143E-05, 5.952E-08)
Rotterdam: (5.950E-02, -4.619E-03, 1.161E-04, -7.184E-07)
Shanghai: (3.910E-02, -2.383E-03, 6.451E-05, -4.660E-07)
Singapore: (4.652E-02, -3.093E-03, 5.985E-05, -4.595E-08)
Sum of all ports: (4.225E-02, -2.585E-03, 6.991E-05, -5.410E-07)

degree 2:
Gdańsk: (2.505E-02, -9.236E-05, -3.827E-06)
Hamburg: (4.540E-02, -1.460E-03, 1.339E-05)
Long Beach: (1.927E-02, -3.143E-04, 8.392E-06)
Los Angeles: (2.309E-02, -2.862E-04, 3.638E-06)
Le Havre: (5.433E-02, -2.963E-03, 4.625E-05)
Rotterdam: (5.353E-02, -3.350E-03, 5.794E-05)
Shanghai: (3.522E-02, -1.560E-03, 2.677E-05)
Singapore: (4.613E-02, -3.012E-03, 5.613E-05)
Sum of all ports: (3.775E-02, -1.630E-03, 2.609E-05)

6.2 Aperiodic arrivals over days of a week (DoW)

6.2.1 Histograms

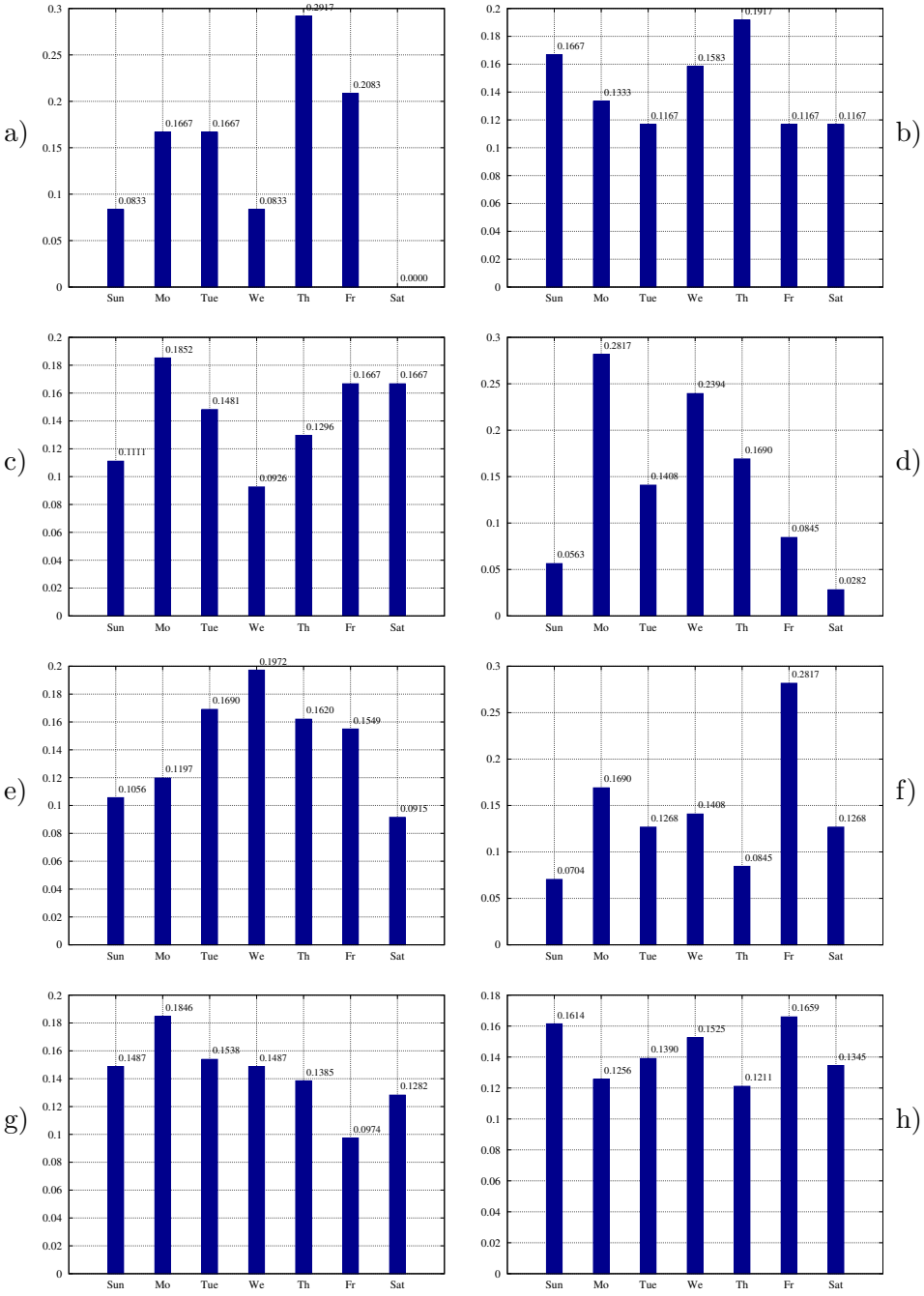

Figure 12: Histograms of aperiodic ship arrivals frequencies (relative to all aperiodic arrivals) over days of week. All classes together. a) Gdańsk, b) Hamburg c) Long Beach, d) Los Angeles, e) Le Havre. f) Rotterdam g) Shanghai h) Singapore.

6.2.2 Fitting distributions

In this section we provide parameters of the best distributions fitting the fractions of total aperiodic arrivals over days of week. Ship size classes are not distinguished. The reader should be aware that the distributions are day of week-agnostic. This means that the fractions of daily arrivals are treated as a set of values not being aware that there is a sequence of days in a week. The best distribution was chosen on the basis of Anderson-Darling statistic. Entry "All ports" represents results aggregated over all ports. The reader should be also aware that the obtained distributions, except for "All ports", are calculated on just 7 data points and quality of fit is low. With so little data reliable fit of continuous distributions may be unwarranted. In general, we recommend using "All ports" distributions. The distribution short names are: γ - gamma distribution, ls - logistic, We – for Weibull. For more details on distribution parameters see [1].

Days of a week
Gdańsk: ls, location 0.14253365, scale 0.05230696;
Long Beach: We, shape 5.5613990, scale 0.1551807;
Los Angeles: We, shape 1.661107, scale 0.159939;
Le Havre: We, shape 4.6678276, scale 0.1566369;
Hamburg: We, shape 5.493224, scale 0.154562;
Rotterdam: γ, scale 0.02531965, shape 5.64210113;
Shanghai: ls, location 0.14362599, scale 0.01355827;
Singapore: ls, location 0.1424664, scale 0.0100078;
All ports: ls, location 0.14130991, scale 0.02846178;

6.3 Aperiodic arrivals over hours of a day (HoD)

6.3.1 Histograms

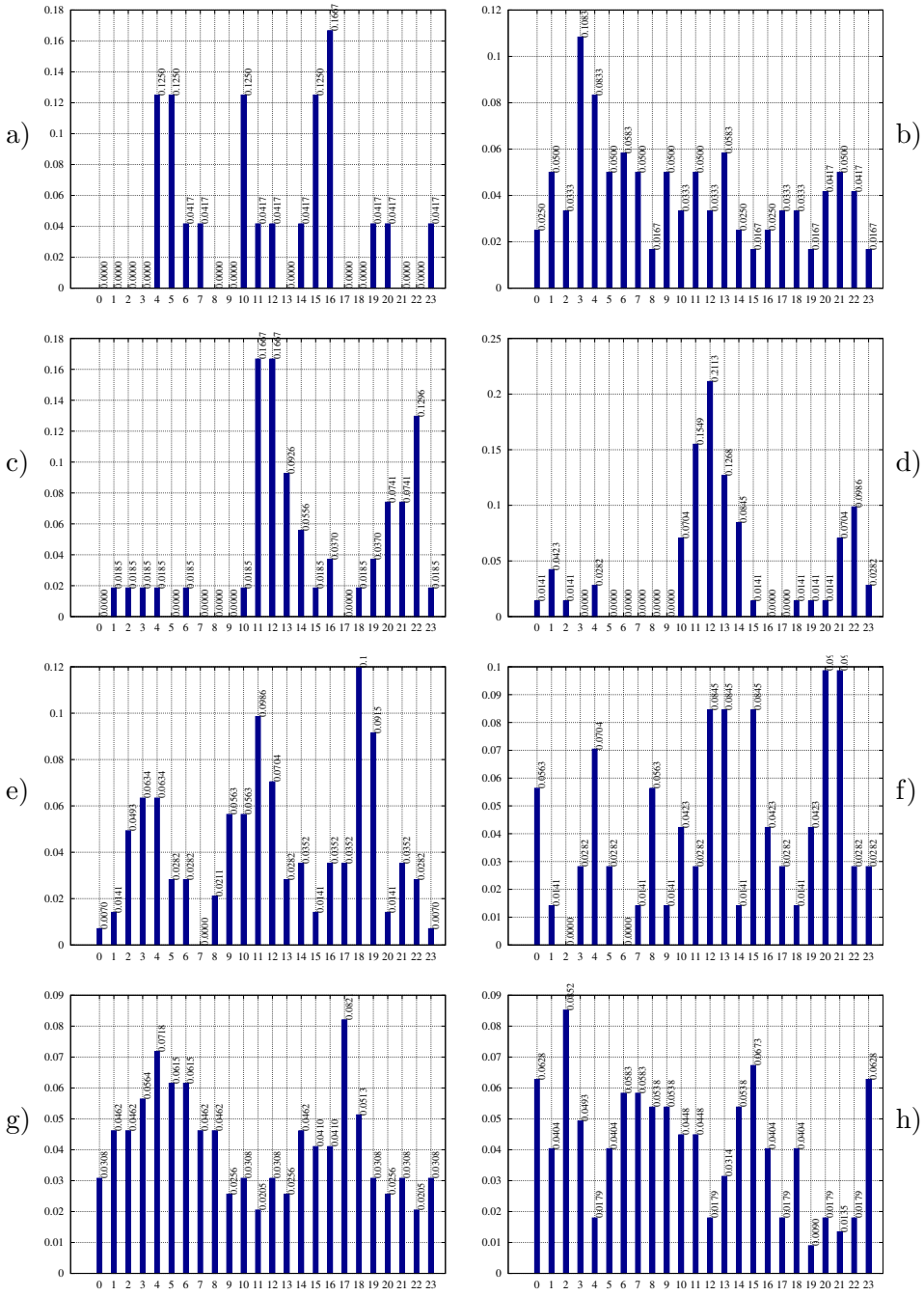

Figure 13: Histograms of aperiodic ship arrivals frequencies (relative to all aperiodic arrivals) over hours of day. All classes together. a) Gdańsk, b) Hamburg c) Long Beach, d) Los Angeles, e) Le Havre. f) Rotterdam g) Shanghai h) Singapore.

6.3.2 Fitting distributions

In this section distributions fit to aperiodic arrivals accumulated over hours of a day are shown. Ship size classes are not distinguished. The reader should be aware that the distributions are time-agnostic. This means that the fractions of hourly arrivals are treated as a set of values while ignoring that there is a sequence of hours in time. Still, we decided to provide even these results for completeness. The reader should also be aware that there are few data points and distribution fit is disputable. Consequently, there are cases which are best according to Anderson-Darling statistic but still do not pass Anderson-Darling `gofstat` test as defined in this function of `fitdistrplus` package R. Such results are marked with a star ("*"). The distributions that passed (actually were not rejected by) the `gofstat` test were preferred over the failing ones. For more details on distribution parameters see [1]. The notation is the same as in Section 6.2.2.

Hours of day
Gdańsk: ls, location 0.03339101, scale 0.02813923; *
Long Beach: ls, location 0.03232727, scale 0.02567877; *
Los Angeles: ls, location 0.03124656, scale 0.02862704; *
Le Havre: ls, location 0.03835805, scale 0.01687393;
Hamburg: γ, scale 0.009688798, shape 4.300531079;
Rotterdam: ls, location 0.03880830, scale 0.01769015; *
Shanghai: γ, scale 0.0057714, shape 7.2195753;
Singapore: ls, location 0.04201991, scale 0.01170694;
All ports: γ, scale 0.005002241, shape 8.329543747;

7 L_j distributions in clusters

This section contains the summary of the parameters of the distributions fitting ship lengths L_j in a certain cluster of a port. These distributions may be applied as alternative to rounding ships lengths to the upper end of cluster range sizes. A reader should be aware that in certain clusters no distribution can be fit reliably due to scarcity of data or narrow range of values. Cases where distribution fitting procedures failed are marked with '*'. In such cases the upper end of class sizes must be used. The best distribution was chosen on the basis of Anderson-Darling statistic. There is no distribution fit in class LB7 which had only one aperiodic ship. The following format of result presentation is used: first the cluster short name is given, next the name of the distribution, and the parameters of the distribution. The distribution short names are: β - for beta distribution, exp – for exponential, γ - gamma distribution, no – for normal, ln – lognormal, ls - logistic, We – for Weibull. Then, the name is followed by the distribution parameters. For more details on distribution parameters see [1]. Since β distribution is defined in interval [0,1], ship lengths were scaled to the upper end of the cluster, i.e., value L_j/c_i is representing ship j in cluster $(c_{i-1}, c_i]$ of ship lengths.

Gdańsk:
GD1, ln, meanlog 4.8539, sdlog 0.0681; GD2, * ; GD3, We, shape 36.0802, scale 179.5612; GD4, * ; GD5, ls, location 284.3670, scale 10.6077; GD6, * ; GD7, *.

Hamburg:
HB1, We, shape 15.5858, scale 132.6229; HB2, ls, location 160.1010, scale 4.7804; HB3, ls, location 198.6465, scale 8.8947; HB4, We, shape 18.2585, scale 266.5379; HB5, ls, location 312.8788, scale 12.5874; HB6, ls, location 366.2584, scale 0.8339; HB7, We, shape 388.6443, scale 399.0706.

Long Beach:
LB1, ls, location 179.4925, scale 7.9933; LB2, ls, location 217.9850, scale 5.3788; LB3, β, shape1 44.5002, shape2 2.3694; LB4, β, shape1 46.3582, shape2 1.6825; LB5, β, shape1 104.1087, shape2 1.3893; LB6, ls, location 356.7786, scale 5.3755; LB7, *

Los Angeles:
LA1, We, shape 21.2431, scale 211.1785; LA2, ls, location 253.9361, scale 3.9852; LA3, β, shape1 125.4677, shape2 2.7138; LA4, β, shape1 99.9067, shape2 0.9868; LA5, ls, location 301.0938, scale 1.0893; LA6, ls, location 331.1834, scale 3.9768; LA7, We, shape 34.3693, scale 365.7491.

Le Havre:
LH1, meanlog 4.9146, sdlog 0.0282; LH2, We, shape 17.4184, scale 197.1736; LH3, ls, location 231.7942, scale 5.7629; LH4, β, shape1 31.3132, shape2 1.0046; LH5, We, shape 72.47073, scale 296.1866; LH6, ls, location 347.8790, scale 11.9925; LH7, ls, location 397.7178, scale 0.8378;

Rotterdam:
RT1, *; RT2, We, shape 47.7901, scale 139.2240, RT3, *; RT4, ls, location 160.8292, scale 3.2152; RT5, ls, location 207.4839, scale 8.4146; RT6, β, shape1 22.3510, shape2 1.4234; RT7, location 284.7580, scale 5.6919;

Shanghai:
SH1, *; SH2, We, shape 27.4311, scale 143.6816; SH3, We, shape 26.5179, scale 172.4476; SH4, β, shape1 24.4726, shape2 2.9468; SH5, ln, meanlog 5.5995, sdlog 0.0487; SH6, β, shape1 30.8465, shape2 2.6373; SH7, ls, location 356.5223, scale 5.2851.

Singapore:
SI1, We, shape 11.83698, scale 159.75541; SI2, no, mean 185.016904, sd 6.311326; SI3, ls, location 212.8532, scale 4.7380; SI4, We, shape 36.6332, scale 257.5605; SI5, ls, location 282.1924, scale 8.2234; SI6, β, shape1 51.9565, shape2 2.7985; SI7, ls, location 365.5421, scale 6.9683.

References

[1] Marie-Laure Delignette-Muller, Christophe Dutang. fitdistrplus : An R Package for Fitting Distributions. Journal of Statistical Software, 64(4), 1–34, 2015. http://www.jstatsoft.org/v64/i04/