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Supplemental Material to *Addressing Spatial Service Provision Equity for Pooled Ride-Hailing Services through Rebalancing*

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1. Introduction

This work provides supplemental material for the study "Addressing Spatial Service Provision Equity for Pooled Ride-Hailing Services through Rebalancing" [1], which was submitted to the 27th ITS World Congress, Hamburg, Germany, 11-15 October 2021. It is divided into two parts. The first part consists of a table that shows detailed outcomes of all simulation runs conducted within the study. The second part is about a detailed comparative analysis of the usage of a grid-based zone system versus a more complex zone system called "Lebensweltlich orientierte Räume" (LOR) [2].

2. Detailed simulation output values and determination of the best parameter set within each approach

Table 1 shows the resulting values of all performance indicators for all conducted simulation runs. Please see [1] for a detailed description of the abbreviations used in run identifiers (runIds), the performance indicators and methodology how to compute them.

Numbers in red mark the six worst values, numbers in blue the six best values, within a column, respectively. Note that runs with a grid zone system are not taken into account for this (see below).

One can derive the importance of T_W^{p95} as a performance indicator for the service provision quality level by each pairwise comparison in table 1 of EVP1, EVD1, EVP5 and EVD5, respectively. While one run has a lower s_W value, which means a higher service provision equity, it offers a lower service quality - i.e. a higher T_W^{p95} and a higher T_W^{mean}.

The following runs were identified to be the most promising ones of their strategy regarding the resulting demand, the ratio of empty VKT, s_W and T_W^{p95}:

- **ED-R2** outperforms all other runs of the ED-R group concerning all performance indicators.
- **FNV6** and FNV5 have by far the best demand and wait times values within the FNV group. FNV6 was chosen for its significantly lower empty VKT ratio in comparison.

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run id	**zones**	**interval [s]**	a	b	$\sum_i t_{i,j}$ **[veh]**	**rides**	T_W^{mean} [s]	T_W^{p95} [s]	**total VKT [km]**	**ratio empty VKT**	s_W [s]
base	-	-	-	-	-	19696	251.8	544	75867	0.2	86.9
ED-R1	447 LOR	300	0.5	0.5	-	22358	229.7	475	86899	0.22	58.8
ED-R2	447 LOR	1800	0.5	0.5	-	25923	211.3	436	98883	0.2	56.2
ED-R2-G	471 squares	1800	0.5	0.5	-	23947	226.3	472	92335	0.21	171.1
ED-R3	138 LOR	300	0.5	0.5	-	16988	255.5	556	67902	0.21	85.7
ED-R4	138 LOR	1800	0.5	0.5	-	6854	337.2	681	37491	0.29	80.6
FNV1	447 LOR	300	0	1	447	24096	218.1	441	93388	0.21	53.4
FNV2	447 LOR	1800	0	1	447	21384	239.2	503	84168	0.22	76.8
FNV3	138 LOR	300	0	1	138	20602	250.7	557	79490	0.21	89.9
FNV4	138 LOR	1800	0	1	138	19726	258.8	570	77368	0.21	85.5
FNV5	447 LOR	300	0	4	1788	26456	201.8	388	117557	0.32	38.0
FNV6	447 LOR	1800	0	4	1788	27125	199.5	397	108777	0.25	43.1
FNV6-G	471 squares	1800	0	4	1844	18699	226.6	419	83391	0.31	69.5
FNV7	138 LOR	300	0	4	552	21048	239.7	487	83960	0.23	56.6
FNV8	138 LOR	1800	0	4	552	21759	238.5	498	84046	0.21	63.5
EVD1	447 LOR	300	0.5	0	1000	23331	217.4	419	95156	0.25	36.8
EVD1-G	471 squares	300	0.5	0	1000	22586	218.3	423	94319	0.27	76.4
EVD2	447 LOR	1800	0.5	0	1000	22172	216.3	428	86650	0.22	42.4
EVD3	138 LOR	300	0.5	0	1000	20762	226.5	456	82005	0.22	47.4
EVD4	138 LOR	1800	0.5	0	1000	20440	241.4	490	82183	0.24	55.7
EVD5	447 LOR	300	1	0	2000	18006	229.0	422	89279	0.37	39.0
EVD6	447 LOR	1800	1	0	2000	18109	226.5	427	79171	0.29	35.9
EVD7	138 LOR	300	1	0	2000	14105	261.0	503	81675	0.45	58.1
EVD8	138 LOR	1800	1	0	2000	16209	245.2	472	73158	0.3	47.4
EVP1	447 LOR	300	0.5	0	1000	26834	206.6	409	109065	0.26	40.9
EVP1-G	471 squares	300	0.5	0	1000	25435	211.9	430	98598	0.22	169.8
EVP2	447 LOR	1800	0.5	0	1000	24973	215.2	430	98404	0.23	50.2
EVP3	138 LOR	300	0.5	0	1000	23119	222.3	452	91752	0.24	50.4
EVP4	138 LOR	1800	0.5	0	1000	23601	223.7	460	90507	0.21	60.5
EVP5	447 LOR	300	1	0	2000	26363	199.9	395	128895	0.38	45.9
EVP6	447 LOR	1800	1	0	2000	26610	197.5	398	111523	0.28	46.6
EVP7	138 LOR	300	1	0	2000	19568	234.9	462	91606	0.34	54.0
EVP8	138 LOR	1800	1	0	2000	22769	218.2	440	93640	0.26	47.8
ED1	447 LOR	300	0.5	0	-	21683	233.0	490	84382	0.21	65.0
ED2	447 LOR	1800	0.5	0	-	24822	222.5	467	94574	0.21	62.2
ED3	138 LOR	300	0.5	0	-	18367	261.0	564	72585	0.21	90.5
ED4	138 LOR	1800	0.5	0	-	5733	346.2	719	32137	0.28	108.0
ED5	447 LOR	300	1	0	-	18318	235.5	492	73443	0.23	74.1
ED6	447 LOR	1800	1	0	-	27469	197.2	400	105290	0.21	43.8
ED6-G	471 squares	1800	1	0	-	26231	202.1	406	101071	0.22	122.0
ED7	138 LOR	300	1	0	-	18908	255.0	554	74097	0.21	84.5
ED8	138 LOR	1800	1	0	-	15684	244.3	498	65073	0.25	60.7
run id	**zones**	**interval [s]**	a	b	$\sum_i t_{i,j}$ **[veh]**	**rides**	T_W^{mean} [s]	T_W^{p95} [s]	**total VKT [km]**	**ratio empty VKT**	s_W [s]

Table 1: Simulation Results

- **EVD1** has the highest demand within EVD and the lowest wait times and s_W at a slightly higher empty VKT ratio than EVD2.
- **EVP1** has together with EVP6 and EVP5 the highest demand, while its service is at a slightly worse level (T_W^{p95}) but more equally spread (s_W). EVP5 has a high empty VKT ratio, whereas empty VKT ratio is best with EVP1. Finally, EVP1 is chosen for it's good service equality and profitability.

- **ED6** has by far the highest demand and the lowest wait times within the ED group, s_W and empty VKT ratio values and thereby outperforms all other runs of the group.

These runs are marked with a grey background in table 1. They are analyzed in more detail within [1]. Moreover, these runs are mirrored with runs using a grid rebalancing zones system, for which the runId ends on 'G'. The following section provides a detailed analysis of these runs and compares them to their equivalents using a LOR zone system.

3. Detailed Comparative analysis to the usage of grid zones

Figure 1 demonstrates the mean wait time per zone in all grid runs. The results for FNV and EVD are very similar, which validates the functionality of the rebalancing system to some extent and is explained above. For all other runs, one finds a cascade-like structure from the inner city to the outskirts, just as for LOR zones. However, rebalancing seems to improve the equality and the level of service. In comparison to the usage of LOR zones, one can determine that for REF2 and ED6, which have zones with a high mean wait time in the south-eastern LOR zones, the change to a grid zone system improves the service quality at that area, but worsens it at other places. For EVP, grid zones seem to perform worse in general, compared to small LOR.

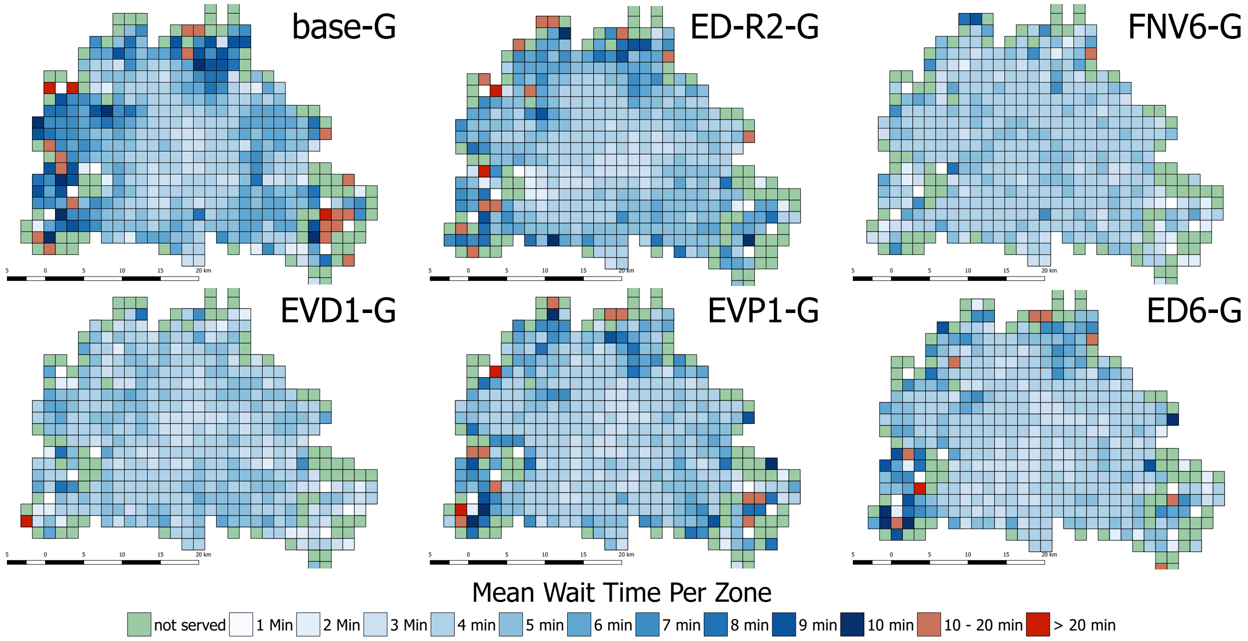

Fig. 1: Spatial Distribution of the Mean Wait Time with a Grid Zone System

For EVD1 and FNV6, the usage of a grid zone produces very low mean wait times values in the outskirt zones, which are partially even lower than in the city center. While their s_W value is considerably higher than for LOR runs, FNV6-G and and EVD1-G outperform all other grid runs in that manner. Moreover, the s_W values are not really comparable between the LOR system and the grid system. Overall, the graphical analysis reveals that spreading vehicles equally in a grid zone system leads to a decent service quality.

Figure 2 displays the spatial distribution of the demand for all grid runs and compares it to the base case. Note that, just as in the main document [1], the colour scale is not linear. One can find that there are neglected zones with zero rides in all cases (compare for example squares in the northern or eastern part). While some zones persist in not being served through all runs, others do not. As the service seems to be generally attractive enough to induce demand for the latter in some of the runs, it is not obvious how to deal with this artefact in terms of the service provision equity. One solution could be to compute a penalty for each zone that is not served.

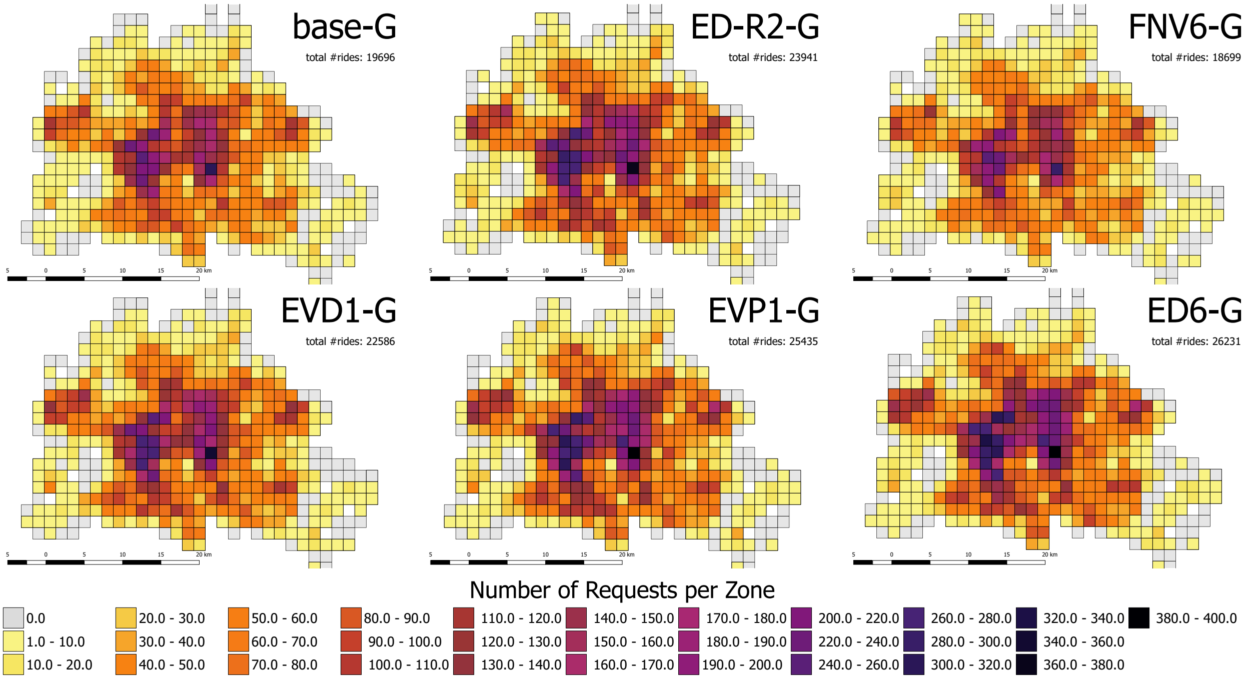

Fig. 2: Spatial Distribution of the Demand with a Grid Zone System

Note that the total demand between EVD1-G and FNV6-G differs notably. As noted above, the grid runs yield a slightly lower demand than their mirrored LOR run, except for FNV6-G, where the difference is roughly 50%. Just as for the LOR, the demand reaction mainly takes place in the inner city and in the south. One finds that the grid runs produce squares across the entire colour scale, in contrast to the LOR runs, as shown in [1].

Acknowledgement

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References

[1] Schlenther, T., Leich, G., Maciejewski, M., Nagel, K., 2020. Addressing Spatial Service Provision Equity for Pooled Ride-Hailing Services through Rebalancing. VSP Working Paper 20-35. TU Berlin, Transport Systems Planning and Transport Telematics.

[2] Senatsverwaltung für Stadtentwicklung und Wohnen Berlin, 2020. Lebensweltlich orientierte räume (lor) in berlin: Planungsgrundlagen. URL: `https://www.stadtentwicklung.berlin.de/planen/basisdaten_stadtentwicklung/lor/`.