Generalistic Assessments of the Potential of Medical Drones in Urban Environment - A study dealing with the transport of medical personnel in the extended area around Stavanger in Norway and the generalization of the results.

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The research questions of the study are based on the project objectives of the AiRMOUR project. The project has received funding from the European Union’s Horizon. 2020 research and innovation programme unter grant agreement No. 101006601

Description of the problem

- A feasibility study showed high expectations of eVTOLs for first aid by transporting medical personnel to the accident site [10]
- R&D projects, being funded by the European Commission (e.g., Flying Forward, Auroura, Amu-LED, AiRMOUR) are actively investigating the future of drone-based medical delivery of goods and passengers, with an increased focus on urban applications.
- None of the personal drones are currently certified for use in Europe.
- The performance classes of personal drones vary widely [11] [12] [13] [14] [15]

Figure: Volocopter and ADAC‘s cooperation in AirRescue, illustration shown in their feasibility study [10]

Figure: Passenger Drone Ehang E210, that is analyzed in ths study and the projekt AiRMOUR.

Research Questions and Objectives

How does the potential for drone applications in urban areas behave when carrying out a micro traffic simulation?

As a result of the project-related collaboration, an Ehang 210 drone and the Stavanger study area in Norway were chosen.

In the showcase of Stavanger, the macroscopic view of the system already shows clear advantages of using drones, which leads to the second research question:

How can clear advantages due to local conditions be classified and how can comparable statements be made across locations?

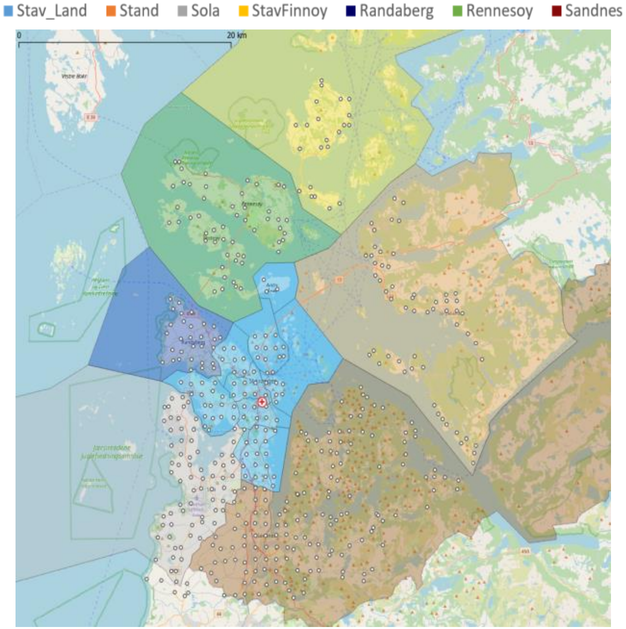

Figure: Administrative districts around Stavanger (Norway)

Methodology

Synthetic ambulance data
- Road network
- Traffic behaviour
- Car following model, dynamics, ambulance behaviour
- Equally distributed sampling point destinations

Groundbased ambulance driving time simulated with SUMO	
Best Case	Nighttime travel time. ~3:00 AM
Normal	Average driving time ~10:00 AM
Worst Case	Rush Hour ~8:00 AM & ~4:00 PM

Synthetic drone data
- linear flight w. ascending, descending
- sensitivity on windspeed
- sensitivity on other dronetypes

$$t_{drone} = \frac{h_t}{v_{acc}} + \frac{d_{lin}}{v_c + v_{air}} + \frac{h_t}{v_{dec}}$$

Linear Drohneflight Ehang 216	
Flight hight	100 m
horizontal flight speed	v_c = 80 km/h ➢ variation for v_c = 120, 260 km/h ➢ Fixed Power reserve at wind v_{air} = +/- 20 km/h
vertical flight speed	+12,6 km/h, -18,8 km/h

Result transformation
- Calculating traveltime benefits
- most beneficial scenarios
- Definition of the transferable system behavior:
  - A. Time to proximity to next primary road
  - B. Time to distance relationship
- Quantitative statements
- Future outlook through speed variations

Stavanger: Calibration of the traffic volume

- Using LeuvenMapMatching to assign traffic couning data on the simulation road network [24].
- Scaled mean traffic for representative night (0.25) and rushhour (2) scenarios.
- Rerouting civil cars with the duarouter tool.
- EIDM car-following model with previous optimized parameters [27]

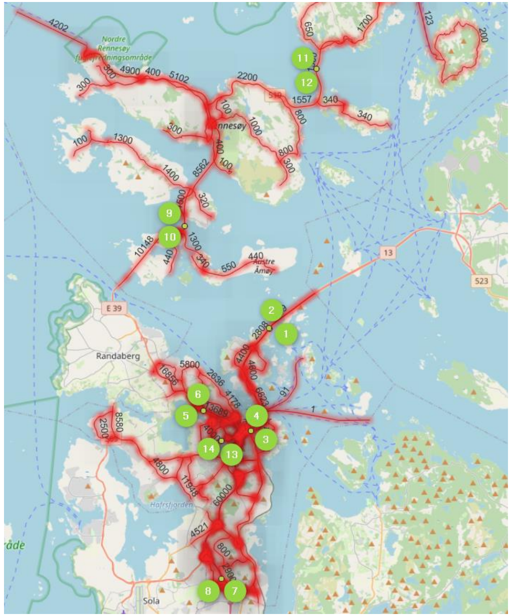

Figure 1: *Annual vehicle count data for the city of Stavanger*

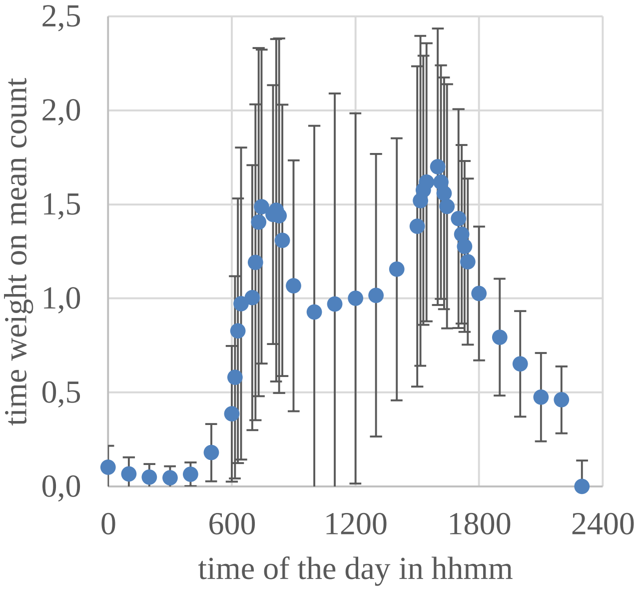

Figure 2: *average time deviation of the vehicle throughput from the average. [25]*

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Behaviour of ambulances in SUMO

- The simulation has to run with sublane model for the usage of emergeny spaces.
- Emergency spaces are formed between the leftmost and the next right-hand lane.
- When overtaking maneuvers across the oncoming lane were activated, errors occurred frequently and the simulation crashed regularly.
- Initially, the emergency lane was formed but not used by the ambulance. Safety distances were parametrized to ensure this function.
  (set minGapLat from default 0.6 m to 0.05 m)
- LatAlignment was set to left, so that the ambulance is oriented to the left lane and has the shortest route to the emergency lane.
- The willingness to encroach laterally on other drivers was set to 100 % with parameter lcPushy.

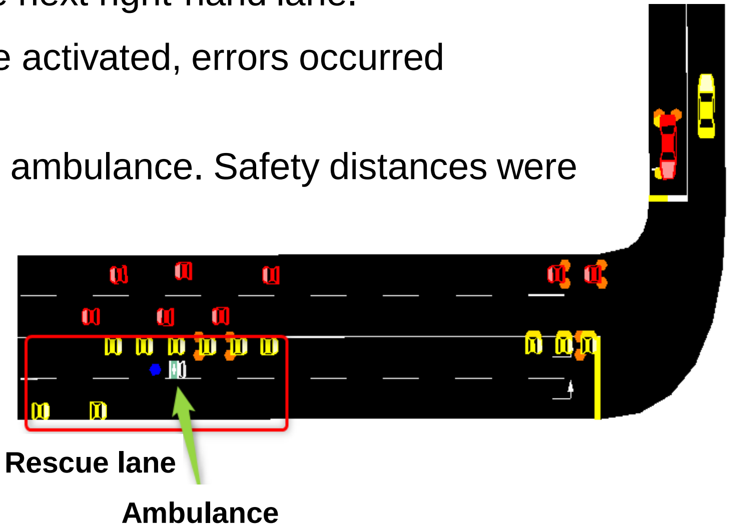


Figure: Extract of test examples.
(Vehicle sizes are displayed distorted in the GUI)

Destination definitions

- To define exemplary analysis trips for ambulances, a separate route file (*.rou.xml) was defined in addition to the general traffic using the “from-” and “toJunction” keys.
- The hospital's rescue station serves as the starting point.
- Destination points are first defined on the basis of a defined 1x1 km grid and then moved to the next node (osmnx, nearest node [26]) in the road network if this is within half the grid size.
- Rescue vehicles are launched in random order with a time delay of 60 seconds

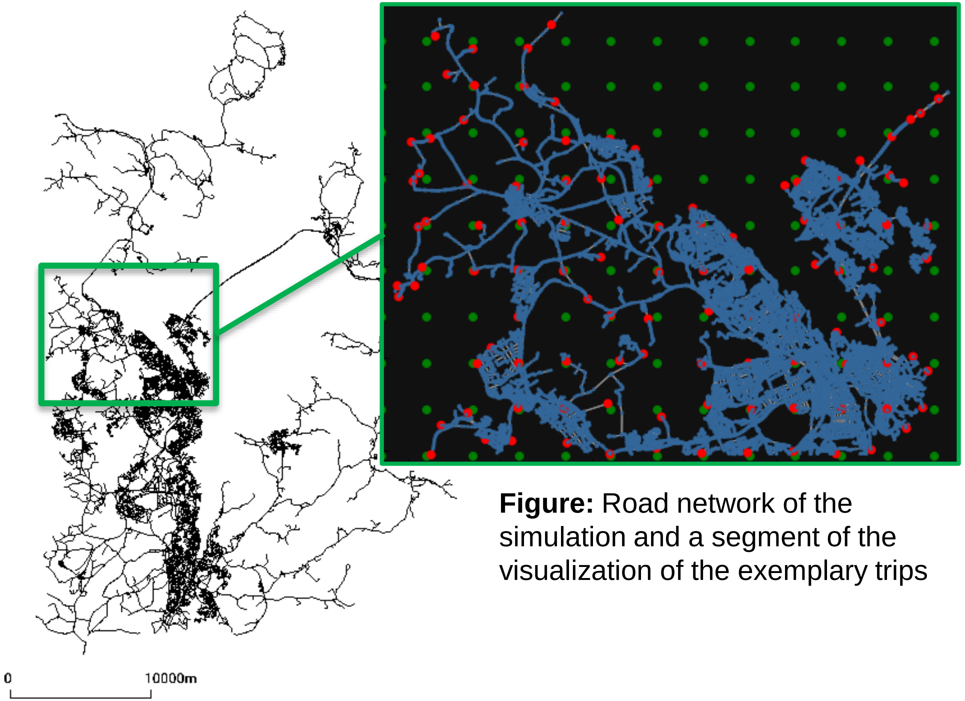


Figure: Road network of the simulation and a segment of the visualization of the exemplary trips

Validation of ground based synthetic EMS driving data

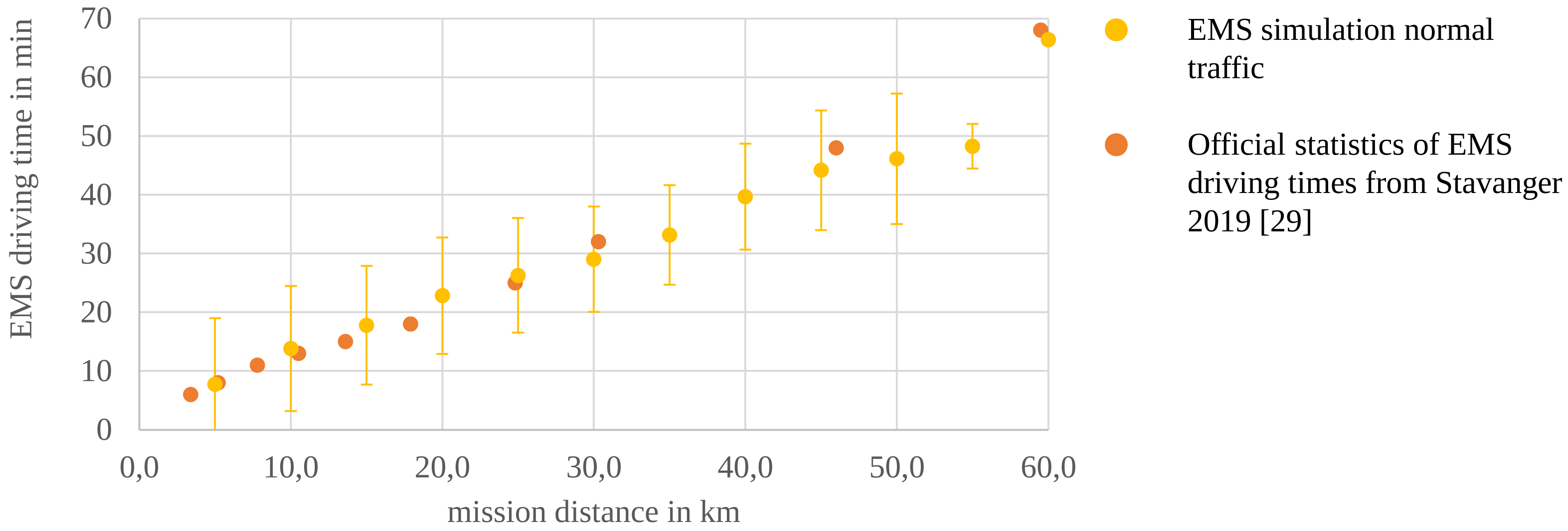


Figure: Validation of the SUMO Ambulance Model

Sensitivity analysis – constant power reserve at wind variances

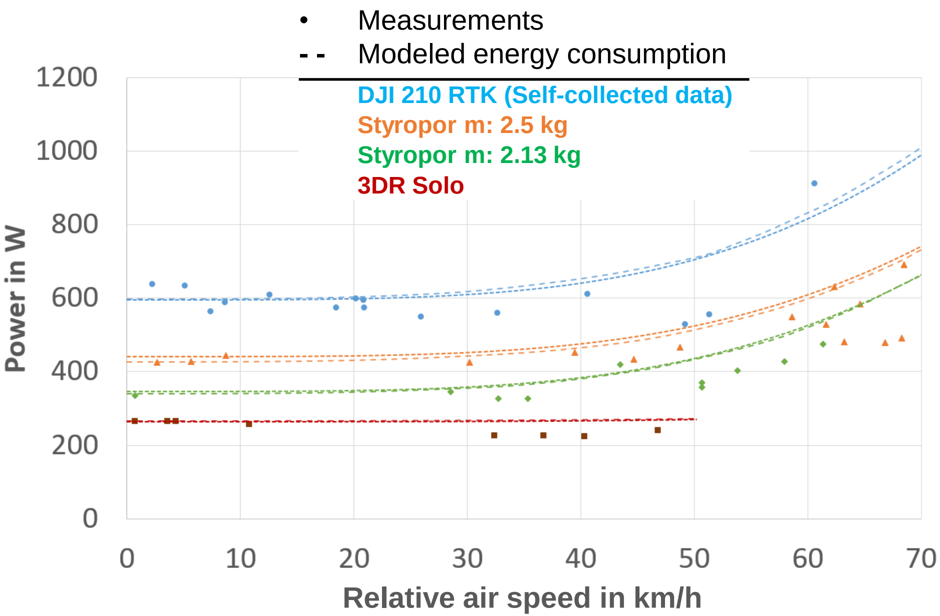


Figure 1: Power consumption over relative Airspeed in km/h modeled according to [31] and enriched with own measurements.

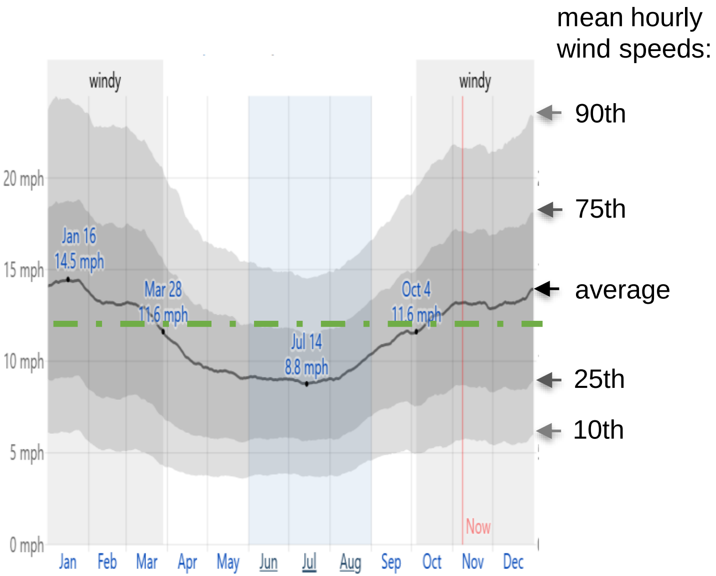


Figure 2: average wind speed stavanger over more than 5 years [32] [32v]

Results: Traffic / Wind variance (most beneficial scenarios)

Figure 1:
SUMO ambulance simulation at mean traffic average wind (zero)

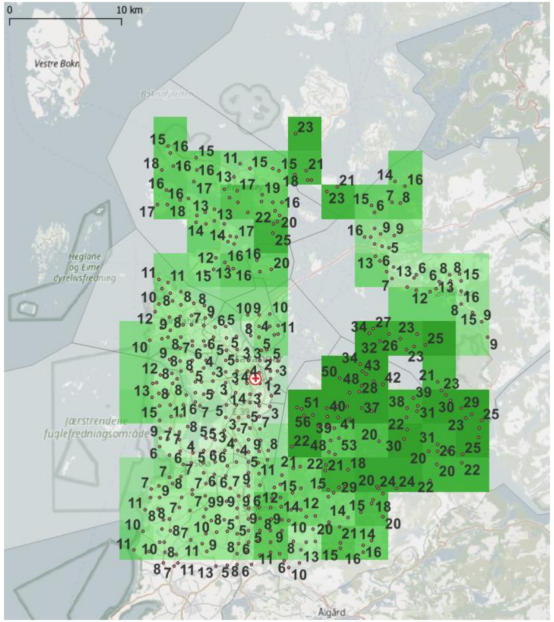


Figure 2:
Most beneficial conditions for drone (tailwind + rush hour)

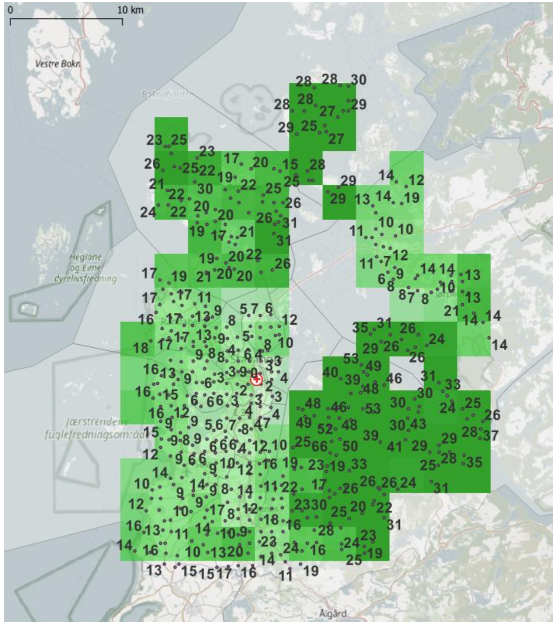
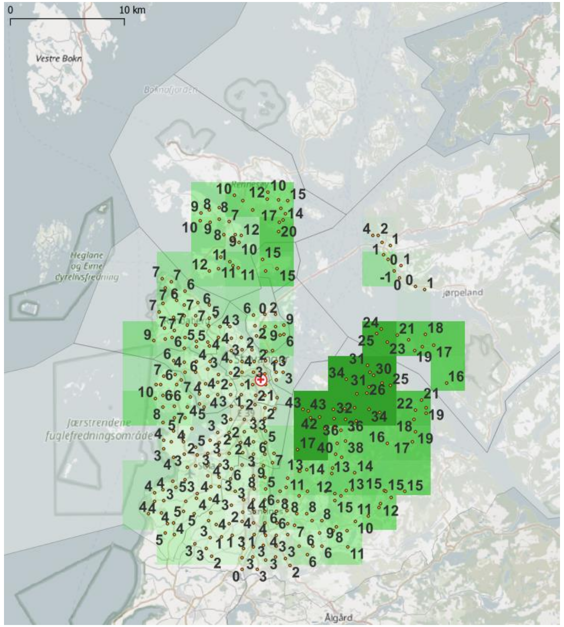


Figure 3:
Most beneficial conditions for ambulance car (headwind + nighttime traffic)



Result classification

The ratio of time savings to the distance traveled on ground

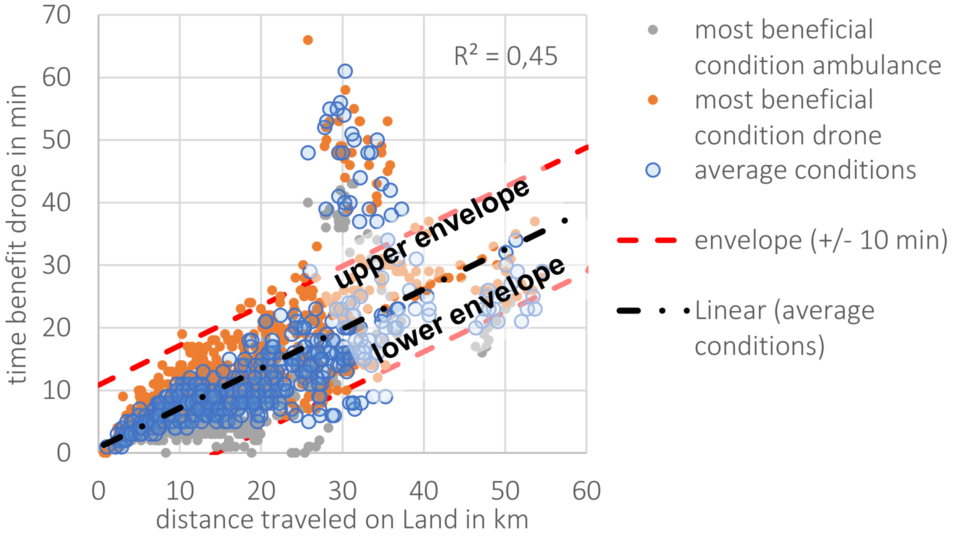
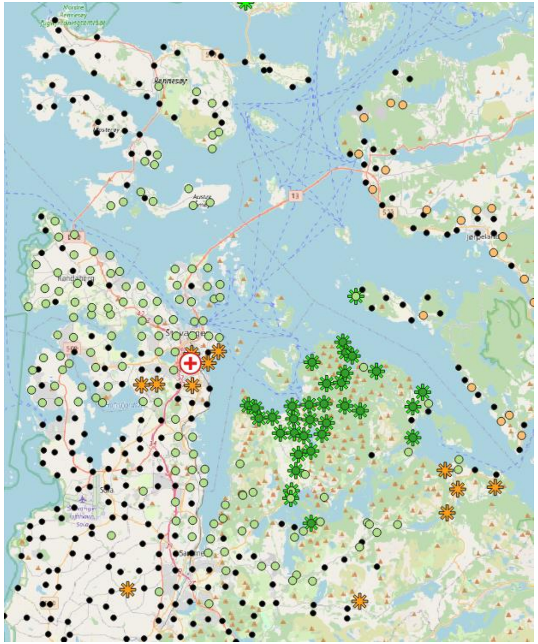


Figure: *Relation of the time advantages when using drones in the EMS sector to the distance to be driven on the ground*

- This method shows a better linearization subjective and though R²
- Outliers above the border are on the neighboring peninsula, which can only be reached on the ground via detours
- Classification method chosen for defining the generalistic behaviour on the average condition.
- Therefore, the term average generalistic behaviour is used (AGB)

Result classification



Categories based on the linearity between time savings to the distance to the next main road:

- ✳ by >10 minutes better than the linearization
- ✳ by >10 minutes worse than the linearization

Categories based on the linearity between time savings to ground-based route length:

- ● **>10 minutes better** than **AGB**
- ○ Within the **upper portion** of the 10-min envelope in the **AGB**.
- • Within the **lower portion** of the 10-min envelope in the **AGB**.
- ● **>10 minutes worse** thanAGB

***Figure 1**, local distribution of classified pseudo emergency locations.*

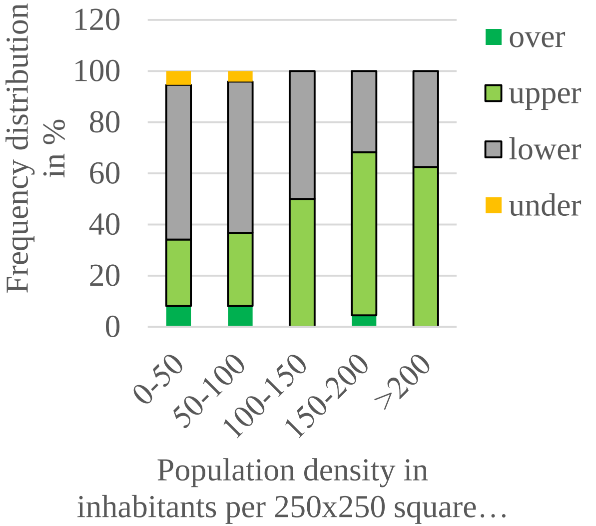


***Figure 2**, Distribution of classes, categorized according to ground transportation distance, by population density.*

Results - Quantitative statements

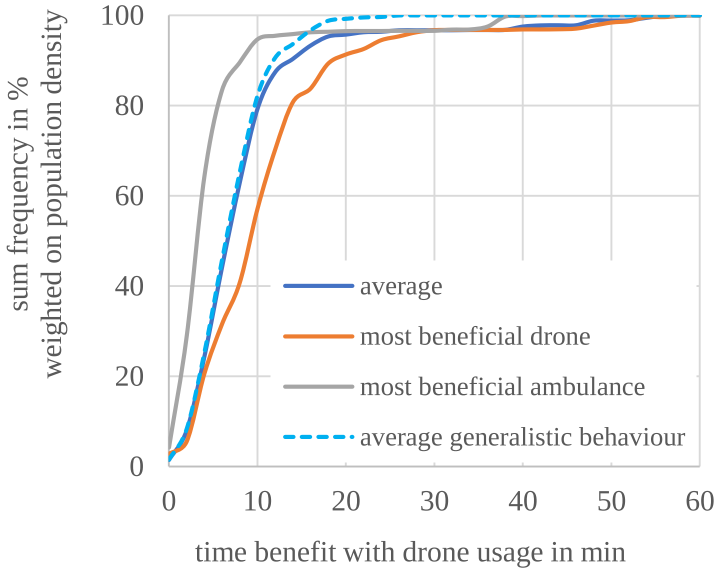


***Figure 1:** Illustration of statistical statements about the results of the different beneficial system behaviors and the data points classified as generalist.*

- cumulative frequency when scaled the likelihood of the simulated EMS missions by population density [34]

- For 80% of anticipated missions, time savings are below:
  - 10 min. at average condition
  - 6 min. for most beneficial scenario for ambulance
  - 14 min for most beneficial scenario for drones

- The majority of the remaining time savings are up to 20 min. for the AGB.

- At Stavanger, the best 5% show benefits of 20-60 min. at average.

Results - future outlook through speed variations

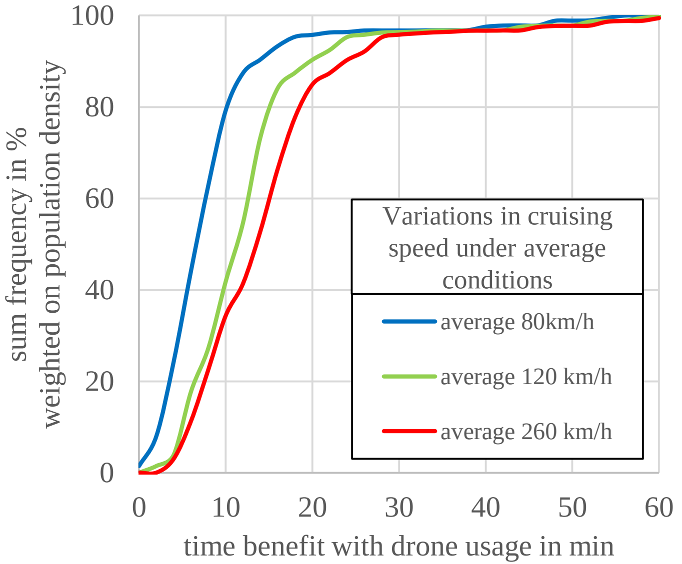


***Figure 1:** Comparable evaluation with variation of the drone's cruising speed at average condition.*

***Table 1:** time advantages in relation to the scaled travel speed (variations)*

	Scaling in relation to the configured drone.				Parameters of the linear approximation between drone flying time and ambulance driving time	
	Percentile of occurrence around Stavanger in %				Min. saved on average, additionally in every journey.	Min. saved / km driven
cruising speed variation	50	80	90	95	a	b
1 (80 km/h)	1.0	1.0	1.0	1.0	0.83	**0.63**
1.5 (120 km/h)	**1.7**	**1.5**	**1.4**	1.3	4	**0.72**
2 (260 km/h)	**2.0**	**1.9**	1.7	1.6	5.20	**0.81**

conclusion

- SUMO was useful to generate georeferenced ambulance travel time data of variable scenarios using a few publicly available data sets. The results of the model correlated remarkably well with the official local statistics.

- A buffer around the **linear ratio** of **time savings to ground-based travel distance** is suitable for defining comparable cross-location statements (**generalistic behavior**).

- **Urban areas** and areas of **high population** density show an increased presence of sample point, that are classified in the **better half of the average generalistic behavior**.

- For 80% of anticipated missions, time savings are below:
  - 10 min. at average condition
  - 6 min. for most beneficial scenario for ambulance
  - 14 min for most beneficial scenario for drones

- The majority of the remaining time savings are up to 20 min. for the AGB.

- At Stavanger, the best 5% show benefits of 20-60 min. at average and 10-40 min. at the most beneficial state of the ambulance.

References

[10] ADAC Luftrettung gGmbH, (2020), Multicopter in the rescue service, Feasibility study on the application potential of multicopters as emergency doctor shuttles, [Online] Available: https://luftrettung.adac.de/app/uploads/2021/02/LRG_Machbarkeitsstudie_engl.pdf [Accessed: 03.05.2023]

[11] Volocopter, August 2019, VoloCity Design specifications, accessed 10.04.2023, [Online] Available: https://assets.ctfassets.net/vnrac6vfvrab/73kYdf0o0kR7Y8XqAz9rEl/40bcf5c38552f6d1fcca71f7fe9736f3/20220607_VoloCity_Specs.pdf

[12] Lilium, October 2023, Lilium Jet specifications, accessed 10.04.2023, [Online] Available: https://investors.lilium.com/static-files/15eb1ad5-0454-4eab-99cb-caf47239eedb

[13] Archer, Archer Midnight on Company Website, accessed 10.04.2023, [Online] Available: https://archer.com/midnight

[14] Archer, 13.10.2022, Archer to Unveil Production Aircraft Midnight™ at its November 16th Open House Event, accessed 10.04.2023, [Online] Available: https://archer.com/news/archer-to-unveil-production-aircraft-midnight-at-its-november- 16th-open-house-event

[15] Airbus, CityAirbus NextGen specifications, accessed 10.04.2024, [Online] Available: https://www.airbus.com/en/innovation/low-carbon-aviation/urban-air-mobility/cityairbus-nextgen

[24] Gade, K., (2010), A Nonsingular Horizontal Position Representation, The Journal of Nav-igation, Volume 63, Issue 03, pp 395-417, July 2010, doi: 10.1017/S0373463309990415, [Online] Available: www.navlab.net/Publications/A_Nonsingular_Horizontal_Position_Representation.pdf,

References

[25] The maintainer of the dataset is Helsingin kaupunkiympäristön toimiala / Liikenne- ja katusuunnittelu. Traffic data from Helsinki, The dataset has been downloaded from Helsinki Region Infoshare service on 14.03.2023 under the license Creative Commons Attribution 4.0.

[26] G. Boeing, “Osmnx: New methods for acquiring, constructing, analyzing, and visualizing complex street networks,” Computers, Environment and Urban Systems, vol. 65, pp. 126–139, 2

[27] Würtz Samuel & Rossa Jonas & Bogenberger Klaus & Göhner Ulrich, (2023), Virtual Testbed for the Planning of Urban Battery Electric Buses, 9th International Symposium on Transportation Data & Modelling, doi: 10.2760/522095

[29] Statistics Norway, EMS driving distance and time statistics, accessed on 16.08.2022 re-trieved from www.ssb.no/statbank/

[31] Theys B, D. S. (2020). flight tests of a quadcopter unmanned aerial vehicle with various spherical body diameters. International Journal of Micro Air Vehicles. doi:10.1177/1756829320923565

[32] Global Modeling and Assimilation Office (GMAO) (2015), MERRA-2 tavgU_3d_udt_Np: 3d,diurnal,Time-Averaged,Pressure-Level,Assimilation,Wind Tendencies V5.12.4, Greenbelt, MD, USA, Goddard Earth Sciences Data and Information Services Center (GES DISC), Accessed: 03.11.2022, 10.5067/DO715T7T5PG8

[32v] Graphical reprocessing of [32], last access on 12.05.2024: https://weatherspark.com/y/52819/Average-Weather-in-Stavanger-Norway-Year-Round

References

[34] Schiavina, Marcello; Freire, Sergio; MacManus, Kytt, (2019), GHS population grid multitemporal (1975, 1990, 2000, 2015) R2019A, European Commission, Joint Research Centre (JRC) DOI: under release, updated on: http://ghsl.jrc.ec.europa.eu/documents/GHSL_Data_Package_2019.pdf