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, Aurora, AmuLED, 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.
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

#### Synthetic drone data
- Linear flight w. ascending, descending
- Sensitivity on windspeed
- Sensitivity on other dronetypes

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

#### Result transformation
- Calculating traveltime benefits
- Most beneficial scenarios

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<table>
<thead>
<tr>
<th>Groundbased ambulance driving time simulated with SUMO</th>
</tr>
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<tbody>
<tr>
<td>Best Case</td>
</tr>
<tr>
<td>Normal</td>
</tr>
<tr>
<td>Worst Case</td>
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<tr>
<th>Linear Drohneflight Ehang 216</th>
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<tbody>
<tr>
<td>Flight hight</td>
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<tr>
<td>Horizontal flight speed</td>
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<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
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<tr>
<td>Vertical flight speed</td>
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</tbody>
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**Definition of the transference system behavior:**
- Time to proximity to next primary road
- Time to distance relationship

- Quantitative statements
- Future outlook through speed variations
Stavanger: Calibration of the traffic volume

- Using LeuvenMapMatching to assign traffic counting data on the simulation road network [24].
- Scaled mean traffic for representative night (0.25) and rush hour (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](image)

![Figure 2: average time deviation of the vehicle throughput from the average. [25]](image)
Behaviour of ambulances in SUMO

- The simulation has to run with sublane model for the usage of emergency 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 IcPushy.

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

EMS simulation normal traffic

Official statistics of EMS driving times from Stavanger 2019 [29]
Sensitivity analysis – constant power reserve at wind variances

- Measurements
- Modeled energy consumption

**DJI 210 RTK (Self-collected data)**
- Styropor m: 2.5 kg
- Styropor m: 2.13 kg
- 3DR Solo

**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

• 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)

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

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)

<table>
<thead>
<tr>
<th>Cruising Speed Variation</th>
<th>50</th>
<th>80</th>
<th>90</th>
<th>95</th>
<th>Min. Saved / km Driven</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1</strong> (80 km/h)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>0.83</td>
</tr>
<tr>
<td><strong>1.5</strong> (120 km/h)</td>
<td>1.7</td>
<td>1.5</td>
<td>1.4</td>
<td>1.3</td>
<td>4.00</td>
</tr>
<tr>
<td><strong>2</strong> (260 km/h)</td>
<td>2.0</td>
<td>1.9</td>
<td>1.7</td>
<td>1.6</td>
<td>5.20</td>
</tr>
</tbody>
</table>
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


References

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


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