Sensitivity Analysis: Decentralised traffic management for constrained urban airspace: dynamically generating and acting upon aggregate flow data

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Parameters to test

The dynamic traffic management method describes several parameters that are set in the method. The sensitivity analysis tests how these parameters affect the performance of the dynamic traffic management method. Additionally, we test the method on the virtual network of Vienna. The following list shows the four different tests of the sensitivity analysis:

1. Cluster distance threshold: 1000 m^2, 4000m^2, 8000m^2, 12000m^2.
2. Percentile of clusters classified as low density: 0th 25th, 50th, 75th.
3. Additional cost value applied to the virtual network: 1.5, 2.0, 2.5, 3.0.
4. Vienna virtual network

Each of these parameters will be studied in a sensitivity analysis in order to see their effect on the method. A traffic demand level of 300 aircraft is chosen for this analysis. Also, as the results of the method showed that the Conflict observations strategy had the least number of intrusions, only that strategy will be compared to the Baseline. Finally, the missions routes are randomly generated and do not take into account the demand. Two hundred randomly selected nodes are chosen, and all other nodes have the same probability of being a potential destination. The following section will describe the effects of each parameter on the intrusions per flight and distance travelled percentage when compared to the Baseline case.

The first three parameters are tested in the city of Rotterdam. These create 320 scenarios (4 cluster distances x 4 percentiles x 4 additional costs x 5 repetitions).

Additionally, for the Vienna virtual network, the baseline case without clustering and the conflict-based strategy are compared to each other with a traffic density of 300 aircraft and 5 repetitions (10 scenarios).

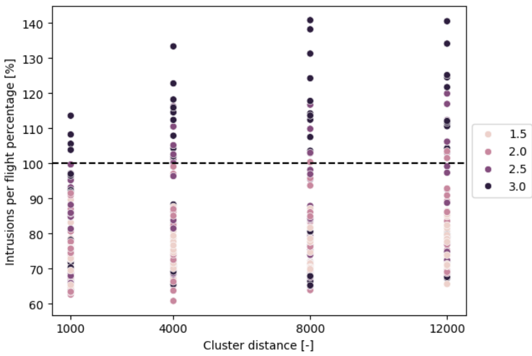
1 Selecting the cluster distance

Figs. 1a and 1b show the Intrusion per flight and distance travelled as a percentage of the baseline in the vertical axis, respectively. The horizontal axis represents the cluster distances. Each dot in the scatter plot represents one simulation. the colour of the dot represents the additional cost multiplier. The dashed line at 100 percent represents the Baseline case.

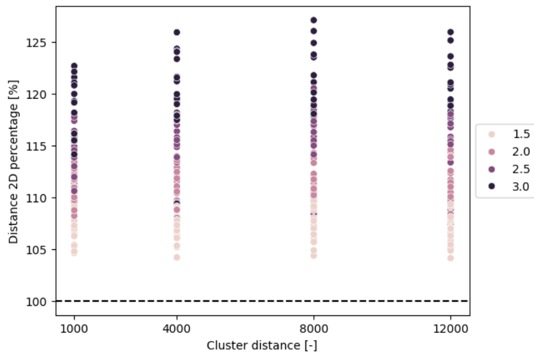
The intrusions per flight percentage do not vary across cluster distance. Interestingly, this suggests that the cluster distance do not greatly affect the parameter. The difference is that at 1000m^2 and 4000m^2 the lowest value reaches around 60 percent. However, the plot does show that higher additional weights tend to have higher intrusions per flight percentages.

In the distance travelled as percentage of the baseline plot, it can also be seen that the cluster distance doesn't have a great effect. However, in this case, it is quite clear that higher additional costs correspond to higher distance travelled. In the case with a multiplier of 3, the distance travelled increases by 25 percent.

Since the cluster distance threshold does not have a great effect on the safety and distance travelled, this work selects 4000m^2 as it is about 3 times the separation minima. This distance of about 100 metres is near the lookahead distance of the conflict detection algorithm.



(a) Intrusions per flight percentage compared to cluster distance and additional cost



(b) Distance percentage compared to cluster distance and additional cost

Fig. 1. This plot shows the intrusions per flight and distance travelled as a percentage of Baseline.

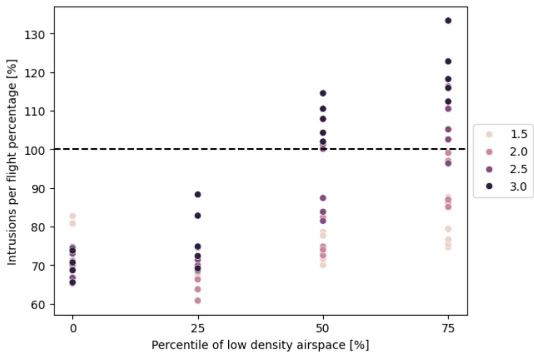
2 Selecting the percentile

Figs. 2a and 2b show the Intrusion per flight and distance travelled as a percentage of the baseline in the vertical axis, respectively. The horizontal axis represents the percentile of clusters that are classified as low density, the rest of the airspace is then classified as high density. For example, if 0th percentile has low density, that means that the other 100 percent of the airspace is high density. Each dot in the scatter plot represents one simulation. the colour of the dot represents the additional cost multiplier. The dashed line at 100 percent represents the Baseline case. Note that these results are only shown for the case with a cluster distance of 4000m^2.

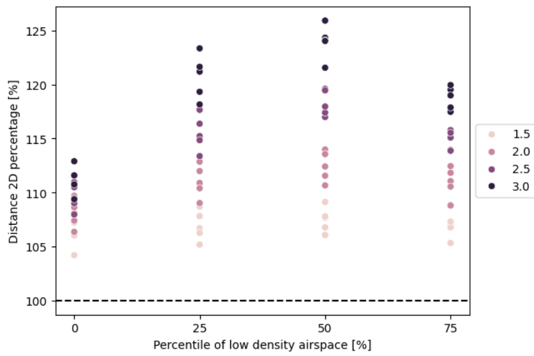
It can be seen that the intrusions per flight increases as the percent of low density airspace increases. However, this is not the case when going from 0 to 25. This actually decreases a bit when 0 percent of observed clusters do not receive an additional weight (low density).

In the distance travelled as percentage of the baseline plot, it is seen that there isn't a great effect on the distance travelled on the percentile. However, it is clear that when 0 percent of clusters are classified as low density, the variance of the distance travelled is lower. This shows that by having 0 percent of the airspace classified as low density, aircraft tend to travel less when compared to the 25th percentile, but they aren't able to go as low in the 25th percentile in terms of intrusions per flight.

Therefore, this work selects uses the 25th percentile for the experiments.



(a) Intrusions per flight percentage compared to percentile of clusters without the additional cost for the scenarios with a cluster distance of 4000m^2.



(b) Distance percentage compared to percentile of clusters without the additional cost for the scenarios with a cluster distance of 4000m^2.

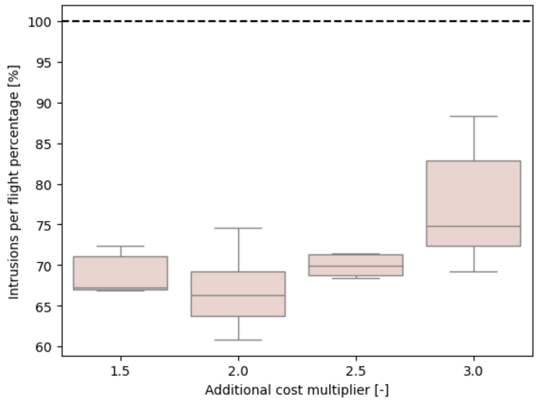
Fig. 2. This plot shows the intrusions per flight and distance travelled as a percentage of Baseline versus percentile of clusters without an additional cost multiplier. The data is only plotted for a cluster distance of 4000m^2.

3 Selecting the additional cost to high density areas

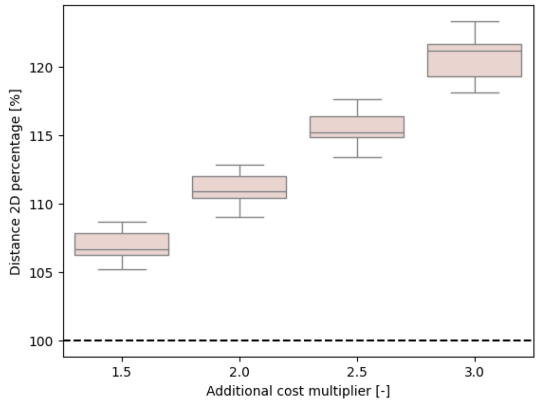
Figs. 3a and 3b show the Intrusion per flight and distance travelled as a percentage of the baseline in the vertical axis, respectively. The horizontal axis represents the additional cost multiplier. The dashed line at 100 percent represents the Baseline case. Note that these results are only shown for the case with a cluster distance of 4000m^2 and 25th percentile.

It can be seen that the intrusions per flight percentages are quite low for all cases. However, the cases with 2.0 and 2.5 have slightly lower averages than the case with 1.5. However, in the distance plot, it can be seen that the additional cost of 1.5 travels about 5 percent less than the case with an additional multiplier of 2.0

Therefore, this work selects uses the case with an additional case of 2.0. This is a tradeoff between safety and distance travelled in the airspace.



(a) Intrusions per flight percentage compared to additional cost for the scenarios with cluster distance of 4000m^2 and 25th percentile.



(b) Distance percentage compared to additional cost for the scenarios with cluster distance of 4000m^2 and 25th percentile.

Fig. 3. This plot shows the intrusions per flight and distance travelled as a percentage of Baseline versus the additional cost multiplier. The data is only plotted for a cluster distance of 4000m^2 and the 25th percentile.

4 Testing the method in Vienna

It is also important to test the dynamic traffic management method under other virtual networks to check its performance. Therefore, we test the method in the Vienna virtual street network from [1] (see Fig. 4). We ran the method with a cluster distance of 4000m^2, additional cost multiplier of 2, the 25th percentile, and a traffic density of 300 instantaneous aircraft.

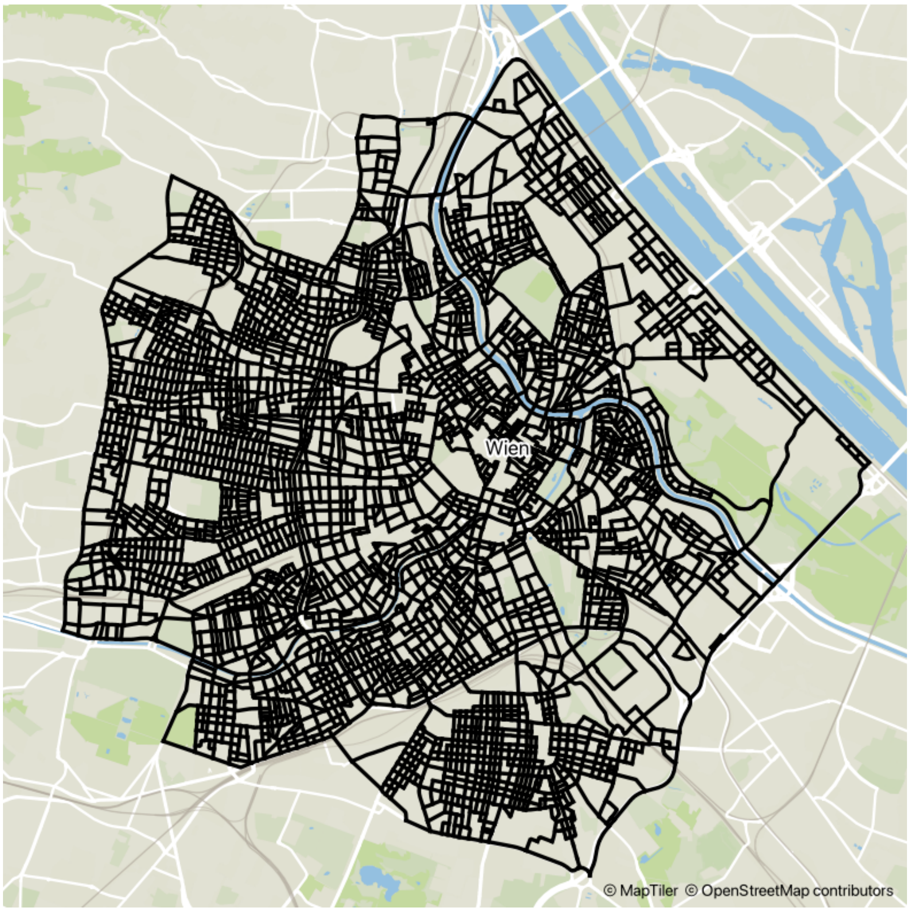


Fig. 4. The airspace of Vienna to test the method under a different virtual network [1].

The results of the simulations can be seen in Table 1. Note that we can see similar results to the Rotterdam virtual network. The conflict-based strategy decreased the number of intrusions per flight by about 25 percent, while increasing the distance travelled by around 7 percent. Note that a further sensitivity analysis might reveal the best parameters for the Vienna virtual network.

	Conflicts per flight [-]	Intrusions per flight [-]	Distance per flight [m]
Baseline (no clustering)	3.93	0.28	5402
Conflict-based	3.48	0.21	5795

Table 1
The results of the sensitivity tests in the Vienna virtual network.

5 References

1. Morfin Veytia, A., Badea, C. A., Ellerbroek, J., Hoekstra, J., Patrinopoulou, N., Daramouskas, I., Lappas, V., Kostopoulos, V., Menendez, P., Alonso, P., Rodrigo, J., Terrazas, V., Bereziat, D., Vidosavljevic, A. & Sedov, L. *Metropolis II: Benefits of Centralised Separation Management in High-Density Urban Airspace* in *12th SESAR Innovation Days* (2022).