Exploring the Impact of Vertiport Network Structures on Urban Air Mobility Operations and Emissions

A MATSim Case Study of the Munich Metropolitan Region

Submitted by

Group 03

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1. Project Overview

This project aims to explore the environmental implications of introducing Urban Air Mobility (UAM) services in the Munich Metropolitan Region (MMR) with a focus on some selected vertiport networks.

According to the European Union Aviation Safety Agency (EASA): "Urban Air Mobility is a new air transportation system for passengers and cargo in and around densely populated and built environments, made possible by electrical vertical take-off and landing aircraft (eVTOL) equipped with new technologies such as enhanced battery technologies and electric propulsion."(*European Commission, Official Website*, 2023). In recent years, academia and industry have performed considerable research on UAM, exploring variables such as cruise speed, flight range, passenger processing, etc. Notably, according to research, the strategic placement of UAM stations, or Vertiport siting, is a critical factor and might be even more significant than the quantity of Vertiports in optimizing UAM networks (Ploetner et al., 2020; R. Rothfeld et al., 2021). This idea is our inspiration to examine vertiport networks generated by two contrasting methodologies: Qualitative and Quantitative.

Furthermore, a survey by the European Commission shows that more than a quarter of greenhouse gases in Europe come from the transport sector. Its contribution to carbon footprint has increasing since 1990, in particular, road transport represents approximately 70% of transport-related GHG emissions (*European Commission, Official Website*, 2023). Therefore, the impact of transport on climate change cannot be ignored. To cut GHG emissions, the European Commission has adopted a set of proposals, which are summarised as the European Green Deal. Germany must achieve at least a 55% reduction in GHG emissions by 2030 (*Germany’s Integrated National Energy and Climate Plan*, n.d.). UAM could be a potential transport mode to contribute to this goal.

Therefore, this study seeks to simulate UAM scenarios within the Munich Metropolitan Region using the agent-based microsimulation framework MATSim. Our objectives are to evaluate the performance of the UAM Vertiport networks in terms of modal shift, travel time savings, traffic congestion, and emissions. We will use the MATSim UAM Extension (R. L. Rothfeld, 2021) to model the UAM scenarios and the MATSim Emission Extension (Horni et al., 2016) to model the emissions. This research could inform various aspects of UAM simulation and modeling and shed light on the impacts of vertiport placements on UAM operations.

Objectives:

Table 1: Goal-indicator system

Goal	Objectives	Indicators
The Strategic Deployment of Urban Air Mobility in MMR	Reduce car dependency	Modal Shift
	Increase Network Efficiency	Travel Time Savings
		Congestion Reduction
Enhancing the environmental quality of the MMR	Improving the air quality	Air emissions: CO_2 and NOx

The reason for Agent-based Modelling:

Agent-based models outperform traditional four-step models for new transport concepts like ridesharing, autonomous vehicles, or UAM. According to (Balać et al., 2018), these transports have limited availability in space and time and require models that can incorporate land use and demographics data for proper simulation (Rodier & Shaheen, 2003). Agent-based models are more adept at addressing these requirements compared to conventional models. MATSim, being an open-source agent-based modeling "framework to implement large-scale agent-based transport simulations (Horni et al., 2016)," is a good option for agent-based modeling "due to it being a research-driven, open-source, and license-free transport-modeling tool (R. Rothfeld et al., 2019)." Besides this, we also want to evaluate the environmental impact of UAM. The calculation of emission in MATSim also depends on individual vehicles and drivers, which can come from the MATSim simulation. Thus, agent-based modeling is a reasonable framework for our project.

2. Methodology

Previous studies on UAM-MATSim in the MMR

In recent times the MMR has been a focus of various entities for UAM research. In 2019, the project OBUAM (Oberbayern Urban Air Mobility), funded by the Bavarian Ministry of Economic Affairs, Regional Development, and Energy, saw the

cooperation between Technical University of Munich, Bauhaus Luftfahrt and Technische Hochschule Ingolstadt, which used the MATSim UAM Extension and resulted in the Ploetner et al. (2020) paper. This project quickly became a blueprint for future UAM research in the MMR, resulting in several further studies where UAM was simulated with MATSim. For our research, we have identified some papers that have inspected the performance of UAM in the Munich Metropolitan Region using MATSim-related methodologies. We developed our parameters for simulation by consulting these studies.
Some key findings from these studies:

1. The OBUAM network: 74 Vertiports determined by Expert Workshops. Later used by Pukhova et al. (2021).
2. The K-means++ network: This was the best-performing network among the other networks developed by Guo et al. (2023) with the clustering technique. According to the author, the K-means++ network performs better than the OBUAM network regarding travel times.
3. According to Pukhova et al. (2021), UAM induces more access and egress car trips than it reduces the primary car trips, thereby increasing the overall congestion, especially in the vicinity of the Vertiports.

Our Simulation Approach with MATSim

In this project, we aim to develop the following MATSim scenarios for the MMR, namely, the Base scenario (non-UAM) and two Future Policy (UAM) scenarios. In accordance with the MATSim User Guide (Horni et al., 2016), the Base scenario will require the MMR road network, Public Transport data, and the initial demand as the input data. We used the ABIT demand data to generate this plan. The MATSim-UAM extension can extend the Base MATSim scenario to integrate UAM by adding the UAM network and UAM vehicle attributes. We used two UAM Vertiport networks for our study: The medium-density network generated by Ploetner et al. (2020) and the Vertiport network generated by the K-means Plus algorithm by Guo et al. (2023). In our simulation, we use the Sub-tour Mode Choice strategy (a predefined MATSim plan mutation strategy) to include UAM as a choosable mode.

We will simulate our created scenarios in MATSim with an iterative loop of executing (mobility simulation), scoring (performance calculation of executed plans using a scoring function), and re-planning (creation/modification of plans for some agents). The process repeats until the average population score reaches a stochastic user equilibrium. MATSim records every action as a MATSim event, which can be used to analyze mode share, travel time, and congestion (Horni et al., 2016).
Furthermore, according to the research by Kickhöfer and Kern (2015), to calculate emissions, we need to combine individual vehicle-based information, such as

kinematic characteristics, parking duration, and accumulated distance, with vehicle characteristics. These attributes can be found in our MATSim Scenario events, which then can be correlated with emission factors from the HBEFA database (Kickhöfer et al., 2016). Based on this theory, a MATSim extension named Emission Modeling is applied, which will be used in our project. From this, we calculate the emission and evaluate the environmental impact of the simulated scenarios. Given that UAM vehicles are electric-powered and do not produce direct emissions. And the primary source of pollution from UAM is the power plant that supplies its energy (Pukhova, 2019). This study only considers non-UAM emissions due to time and resource limitations.

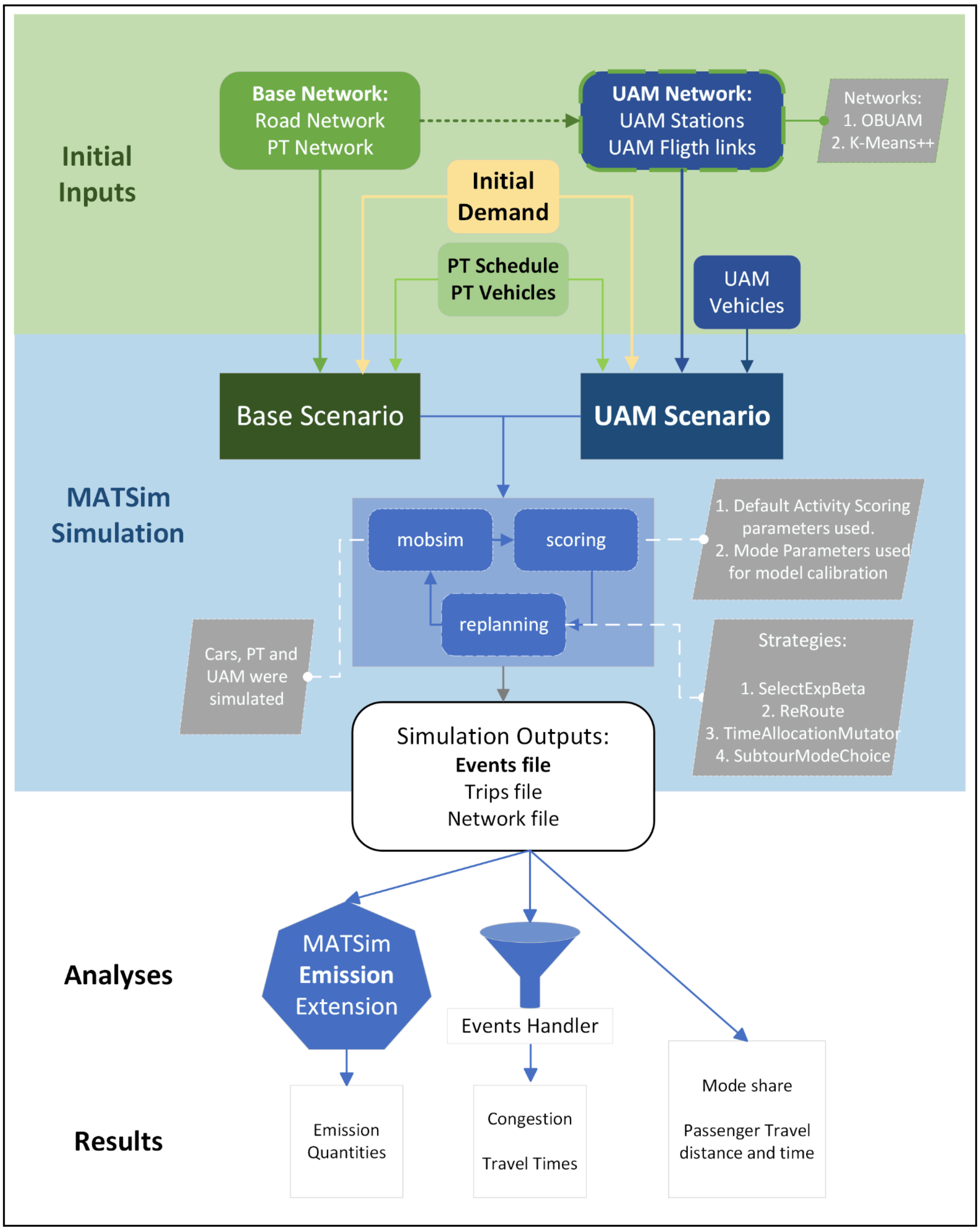


Fig. 1. Project Work Flow.

3. Network Generation

Study Area

Our study area is the Munich Metropolitan Region, which encompasses the cities of Munich, Augsburg, Ingolstadt, Landshut, and Rosenheim and is a part of Bayern. The population is approximately 4.5 million, with 444 municipalities ("Munich Metropolitan Region," 2024).

The modal split of the study area was obtained from the *Mobilität in Deutschland – Publikationen* (2017), and the average across modes was self-calculated. We have considered the modes Car Driver and Car Passenger similar to simplify the simulation. This modal split will be used later for model calibration and validation.

Table 2: Mode share of MMR (*Mobilität in Deutschland – Publikationen,* 2017).

District	Walk (%)	Bike (%)	Car driver (%)	Car passenger (%)	PT (%)
Ingolstadt	20	22	36	13	9
Munich	21	13	41	13	12
Rosenheim	15	11	49	17	8
Landshut	16	10	51	17	6
Augsburg	20	12	48	15	6
Average	18.4	13.6	60		8.2

Data Source and Filtration

The OSM data for Bayern was used to generate the network file. The file was accessed from (*Geofabrik Download Server*, n.d.). The network was further filtered with Osmium (*Osmcode/Osmium-Tool*, 2013/2024), the sample command is in Appendix (a).

Study Area Extraction

The MMR is a subregion of Bayern. The outer boundary of the Traffic Analysis Zones developed by Molloy & Moeckel (2017) was to get the MMR. A buffer area around the outer boundary was introduced to avoid losing the relevant network (Appendix b).

Integrating Public Transport (PT)

The *Liste deutscher Tarif- und Verkehrsverbünde* lists all tariff and transport associations in the transport system of the Federal Republic of Germany (*Datei*, n.d.). We have consulted this list to identify transport agencies in our study area and included relevant long-distance rail routes. The list of chosen transport agencies is in the Appendix (c). Finally, we used the chosen list of agencies to generate filtered GTFS data (*GTFS.DE - GTFS Für Deutschland*, n.d.). (Appendix d)

Next, we used the MATSim PT2MATSim contribution (*Matsim-Org/Pt2matsim*, 2016/2024). We used CreateNetwork.java to create the PT-enabled network, CreateSchedule.java to create the PT schedule and vehicles, and finally, MapSchedule2Network.java to map the schedule to the network.

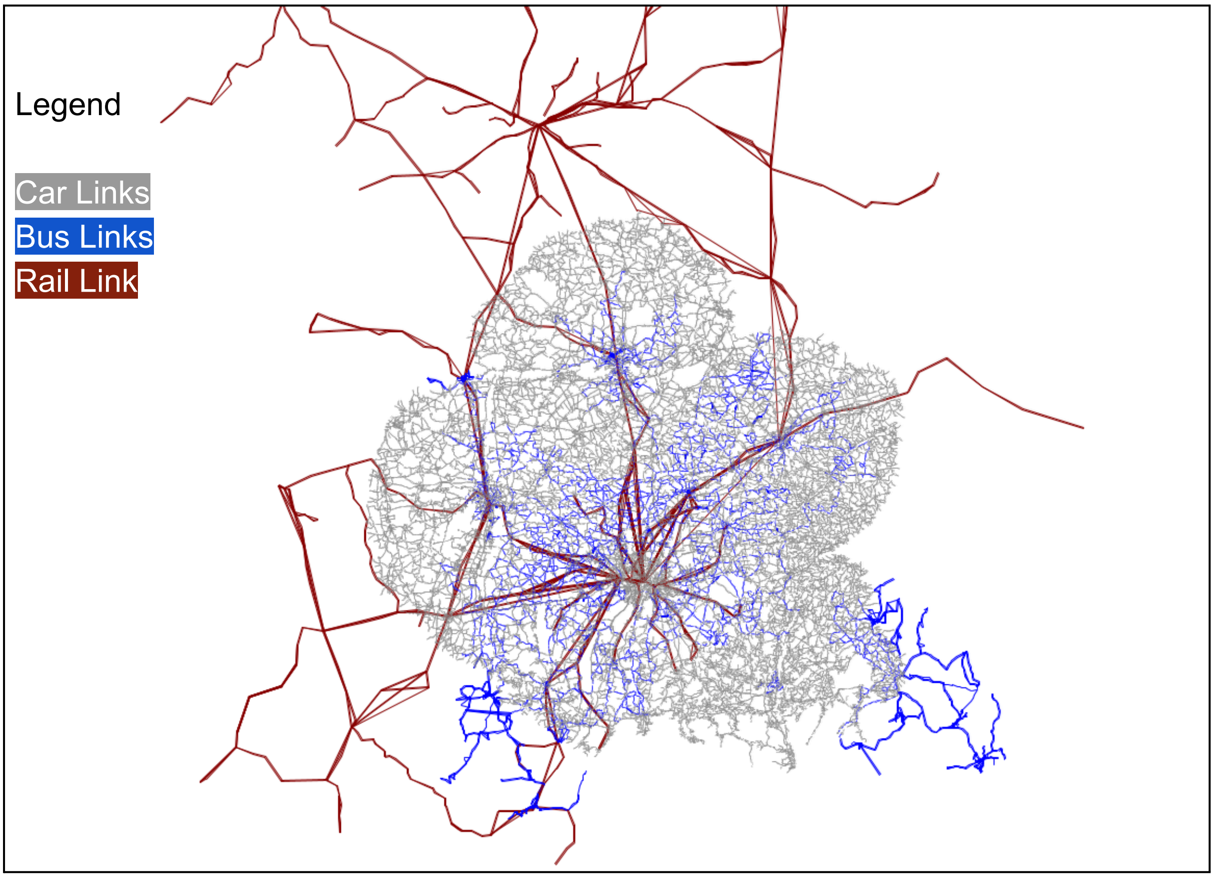


Fig. 2. PT-enabled MMR Road Network.

Transit Schedule and Transit Vehicles

Table 3: Public Transport PCE modification for 1% scenario

PT Vehicle	Passenger Car Equivalents (PCE)	Capacity Seats
Bus	0.15 (changed from 3)	5
Rail	27.1 (no change)	20
Tram	5.2 (no change)	10

It is to be noted that the decision to keep the original PCE values of Rail and Tram was not reasonable. Since, for the 1% scenarios, the Flow Capacity Factor and the Storage Capacity factors are reduced, but the number of operating PT vehicles remains the same, thus we need to reduce the PCE of all PT. We couldn't rectify our fault due to time constraints.

4. Demand Generation

We used the ABIT demand data's legs.csv for the MMR to produce the initial demand. We leveraged the MATSim API to construct the plans file. Each line in legs.csv provided comprehensive data to form a plan, including the initial activity, leg mode, travel time, subsequent activity, and their respective timings and locations. The initial demand or plans store each person's chain of activities data and are required for MATSim simulation. We added demographic details like age, gender, and income to each person but didn't use them in our simulation. (Appendix e)

Sample Size and Demand Processing

We chose 1 percent population on Wednesday (48:00:00 and 72:00:00 hours) as our simulation population and time period. Wednesday is chosen for being mid-week, minimizing weekend influence. We have included all the activities from the ABIT demand and adapted them to follow MATSim lowercase convention. For modes, Car Driver and Car Passenger were combined and imported as MATSim car mode. Train, bus, and trams were combined and imported as PT mode.

5. MATSim Configuration

To configure the MATSim run, we have used a combination of a precomposed MATSim Config file and a Java class to edit and run the config file. The MATSim config file is based on the default MATSim configuration, but some important changes were made for the study. These are discussed below.

Modifications in the config file:

- activityParams: For each activity (home, work, etc), a new activity type was generated. Associated "typicalDuration" and "minimalDuration" were set, obtained from statistical operations on the the demand data.
- modeParams: We experimented with the Marginal Utility of Travelling and Alternative Specific Constants to calibrate the model to match the mode share defined by Table 2, an approach recommended by (Horni et al., 2016).
- qsim:
    - flowCapacityFactor: set to 0.01 for 1% population.
    - storageCapacityFactor: set to 0.105 for 1% population.
- strategy: “fractionOfIterationsToDisableInnovation” set to 0.8 and “maxAgentPlanMemorySize” to 5. The specific strategies used are as follows:
    - SelectExpBeta, with weight 0.5.
    - ReRoute, with weight 0.25.
    - TimeAllocationMutator, with weight 0.25.
    - SubtourModeChoice, with weight 0.25.
      Behavior set to “fromSpecifiedModesToSpecifiedModes”, “chainBasedModes” set to “car, bike”, "considerCarAvailability" to true, and "modes" to "car, pt, walk, bike". In UAM scenarios, “uam” was added to the modes.

Modifications through the Java Class:
We introduce a “pcuThresholdForFlowCapacityEasing” with a value of 0.05 for 1% scenarios.

6. Scenarios

a. Non-UAM Base Scenario

- PT-enabled ground transport road network
- Modes: Car, PT (Bus, Tram, Rail), Bike and Walk

Validation:
The scenario was validated according to Table 2 by running multiple iterations. The final validated parameters were:

Table 4: Parameters for Model Calibration.

Car Parameters			PT Parameters		Bike Parameters		Walk Parameters	
mut	mdr	cnst	mut	cnst	mut	cnst	mut	cnst
-6.00	-0.0002	-3.00	-6.00	-10.00	-6	-3	0	5

Here, “mut” means marginal utility of money, “cnst” means Alternate specific constant, and “mdr” = monetary distance rate. We mostly used Alternate-specific constants to calibrate according to the MATSim Handbook. The monetary distance rate is a standard for Germany. (Horni et al., 2016)

The calibration results were as such:

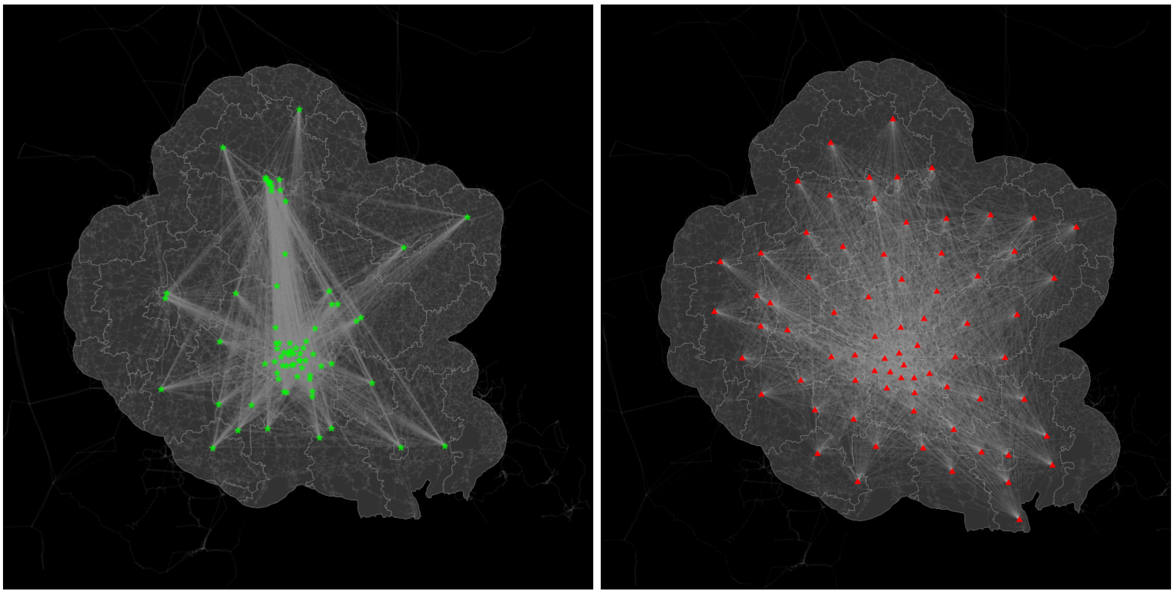
Table 5: Model Calibration Results

Mode Share (Target)			
Car (60%)	PT (8.2%)	Bike (13.6%)	Walk (18.4%)
60.59 %	11.95%	11.84%	15.60%

b. UAM Scenarios based on Vertiport Network:

i. **OBUAM Network:** UAM Network with 74 stations overlaid on Non-UAM Base Network (Fig. 3a) (Ploetner et al., 2020)

ii. **KM++ Generated Vertiport Network:** UAM Network with 74 stations generated by K-Means Plus clustering method (Fig. 3b) (Guo et al., 2023).



(a) OBUAM Vertiport. (b)The K-means++ Vertiport

Fig. 3. UAM Vertiport Networks

7. Results

a. Modal Share

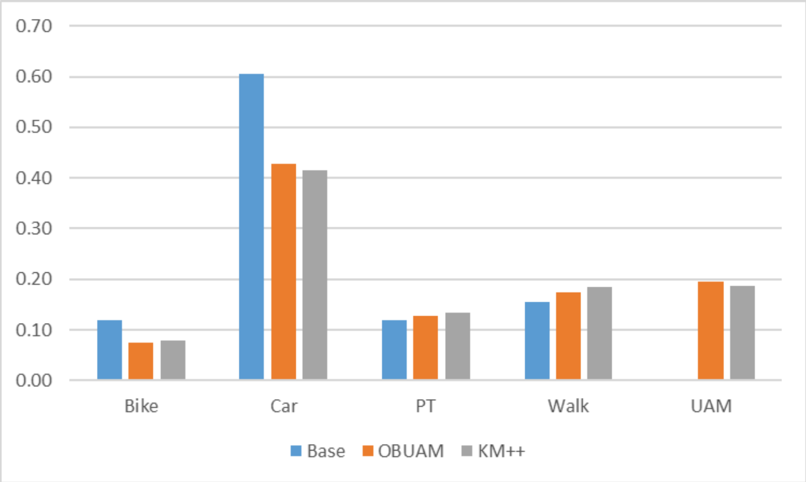


Fig. 4. Final Mode Share from Simulation.

From the graphs in Fig 3, in both the UAM scenarios, the car share decreased, giving way to UAM shares. In addition, we can see a slight increase in PT and walk, and some decrease in Bike shares.

b. Passenger kilometers Travelled

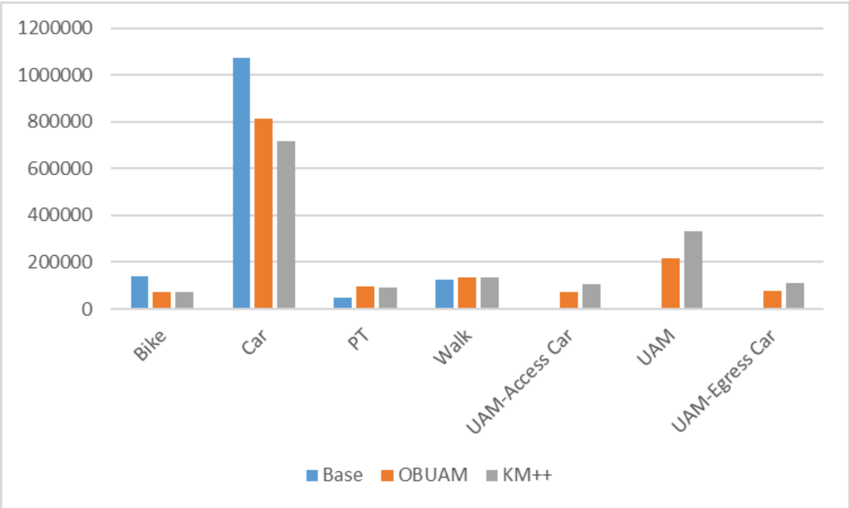


Fig. 5. Passenger Kilometers Travelled by Modes.

Fig. 5 representing Passenger Kilometers traveled corroborates the modal share analysis. Both the UAM scenarios decrease passenger travel by car. The KM++ scenario generates more UAM-related travel distance than the OBUAM.

c. Passenger Hours per Mode

Further confirming our analysis, in Figure 6, we can see a substantial reduction in hours traveled by car for UAM scenarios. We also observe an increase in walking, and PT, while a decrease in biking for UAM scenarios compared against the Base. Also, in accordance with prior charts, passengers ride longer hours in UAM and UAM-related access and egress car modes.

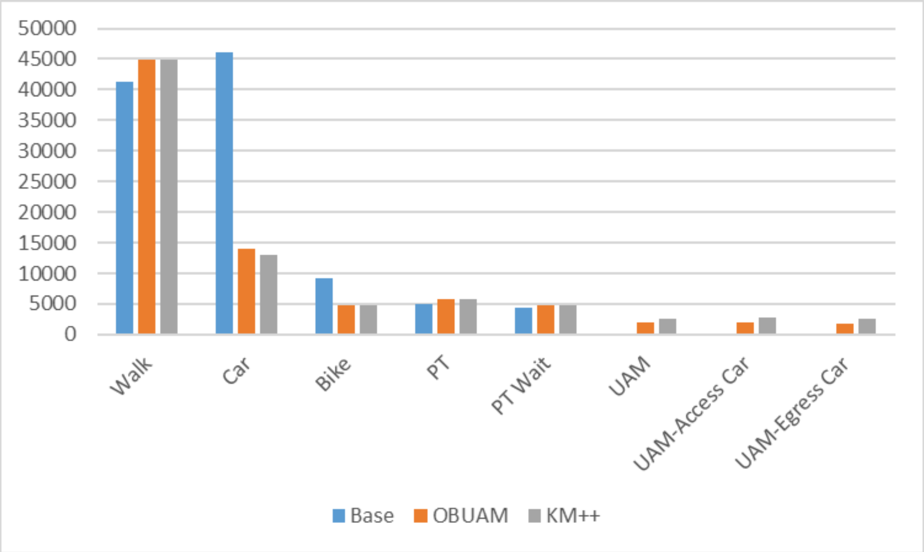


Fig. 6. Passenger Hours Traveled for All Modes.

d. Travel Time for UAM

The KM++ scenario, registering higher passenger kilometers and hours, naturally accumulates more average travel time than the OBUAM. (Appendix h)

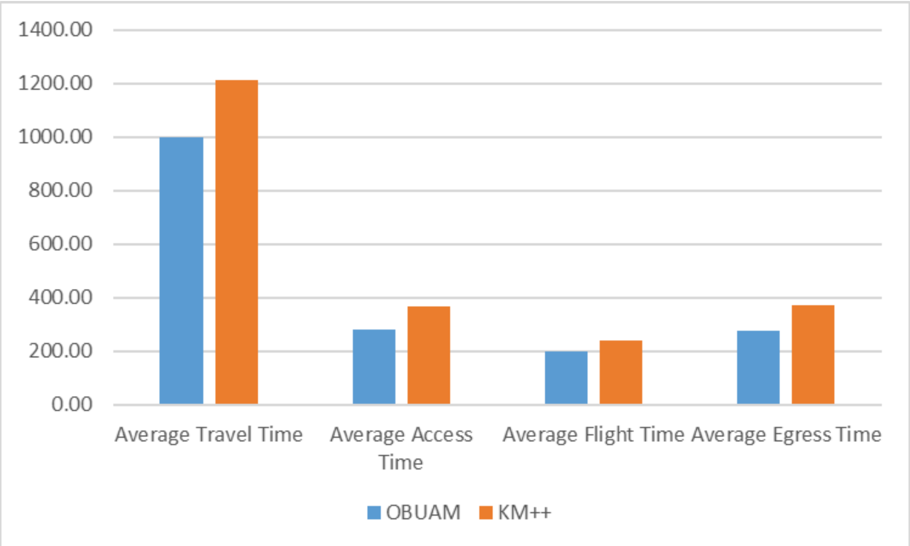


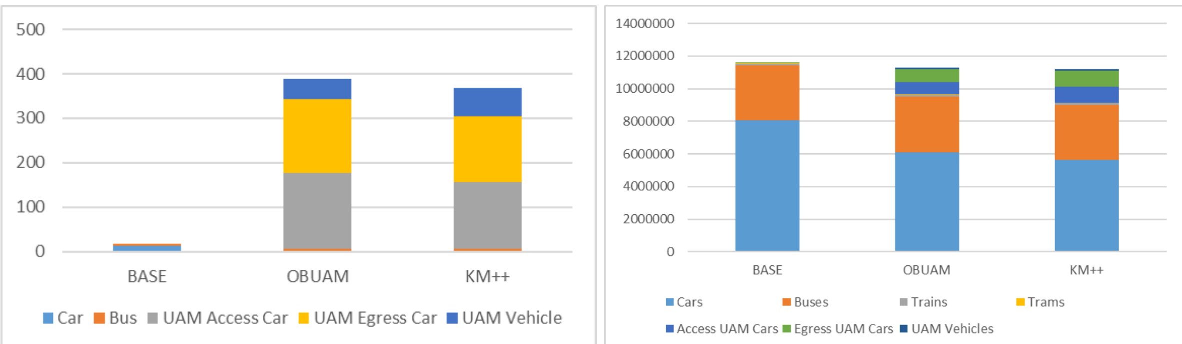
Fig 7: Travel Time Savings for UAM

e. Congestion Analysis

The chart shows the average congestion in seconds faced by each vehicle for all the vehicle types in our scenarios. We can observe an unnatural congestion value for Train. The incorrect value of the PCE can explain this set for the train (27.1) and the tram. However, the congestion impact is not obvious for the tram since it has a low initial PCE value (5.2) and a very small network (402 links). We will ignore trains and trams for further congestion analysis. Without trains and trams, we can observe that the UAM scenarios are more congested than the Base (figure 8a).

Table 6: Average Congestion for each Vehicle

Average Congestion per Vehicle in Seconds	BASE	OBUAM	KM++
Car	12.42	0.82	0.88
Bus	6.03	4.06	4.06
Train	727.93	283.78	282.53
Tram	16.73	6.61	6.61
Access UAM Car	-	171.28	152.08
Egress UAM Car	-	166.60	147.13
UAM Vehicle	-	45.18	65.03
Total	**763.11**	**678.33**	**658.34**
Without Trains and Trams	**18.45**	**387.94**	**369.19**



(a) Congestion for each vehicle type. (b) Count of all vehicles.

Fig. 8. Congestion and Count.

Figure 8 (a) shows an increase in congestion for both the UAM scenarios, where the main sources of congestion are the UAM-related vehicles. But in figure 8 (b), we can see the total count of vehicles for all the scenarios stays the same. Here, the original car modes decrease, and access and egress modes increase for both the UAM scenarios compared to the Base. This poses a contradiction since a similar number of vehicles generate very different congestion amounts. (Appendix g)

f. Investigating UAM Links

In the MATSim-UAM extension, a Vertiport station comprises of a Ground Link (road-ground access, used by cars), Station Link (ground access-flight access, used by cars and UAM), Vertical Flight Link (flight access-flight link, used by UAM), and Horizontal Flight Link (connecting two vertiports for UAM) (figure 9a). Our investigation revealed that, on average, the UAM Station Links, connecting the ground and flight access, and shared by Cars and UAM modes, were extremely congested (figure 9b). This singular station link per vertiport is used by the cars and UAMs to pick up and drop off passengers. In our simulation, a generic Station Link has a 1.0 m length, 99999.0 capacity, and 400.0 Freespeed values. Inspecting Station Links, we found nearly all “Link Leave” events take 1 second, suggesting the reduced Flow Capacity is not the problem. We also found that the “Enter Link” events take a range of values, unnaturally spiking at the 72nd second. We should note that both cars and UAM didn’t have any PCE reduction; therefore, they may be considered 100 instances of each.

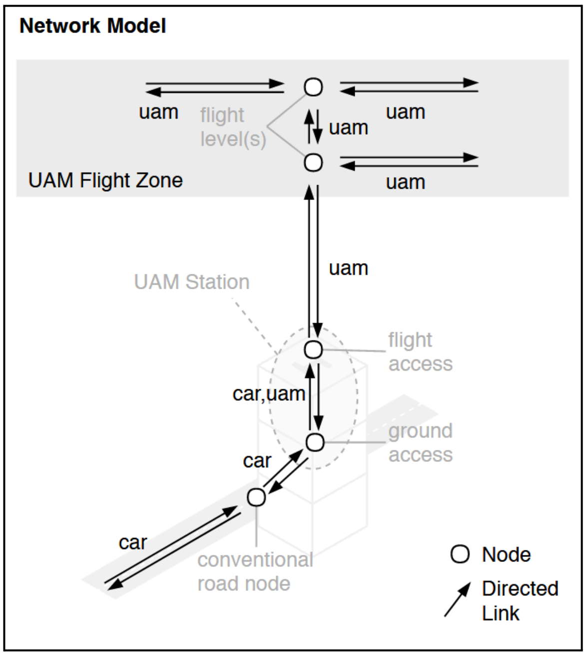


Fig. 9. UAM network design schematic diagram (R. L. Rothfeld, 2021)

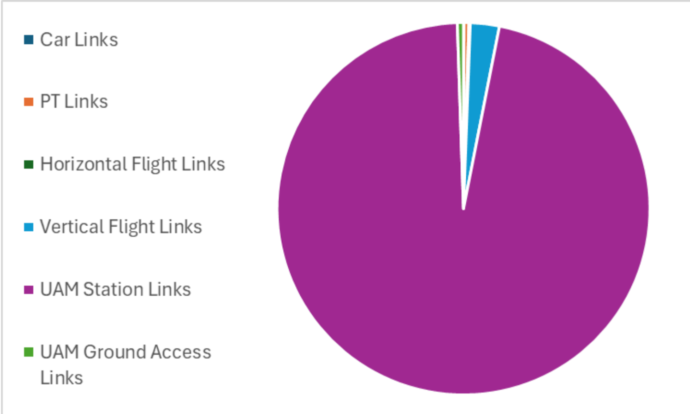


Fig. 10. Pie diagram of congestion by Link type for the OBUAM scenario.

One possible reasoning is the way the Congestion Handler calculates the congestion. It uses the free speed of the link and the link length to calculate the earliest possible link exit time and calculates the difference from real link exit time to produce excess time or congestion. Since our link is 1 m and the free speed is 35 m/s, the handler calculates the earliest possible exit time to be 0.0285 seconds. But MATSim has the lowest timestep resolution of 1 second; as a result, the vehicles can only leave after a minimum of 1 second. A single UAM trip involves traversing the Station Link twice, making the timestep-induced congestion of 1.944 seconds per trip. This trip includes UAM and UAM access and egress modes, as the link is shared.

g. Vehicle Kilometers Travelled

From Figure 11, we can observe that the total vehicle kilometers traveled for KM++ is slightly higher than OBUAM, while the latter is higher than the Base. The decrease of original car kilometers is restored by access and egress UAM car travels (Appendix g).

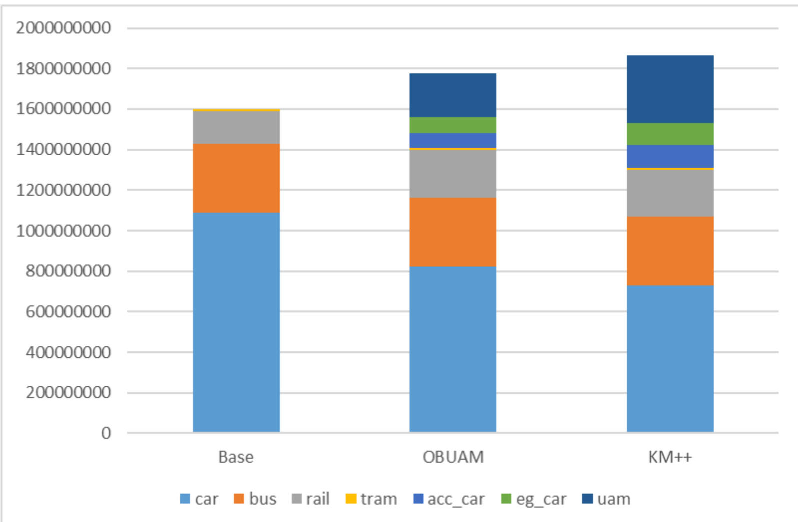
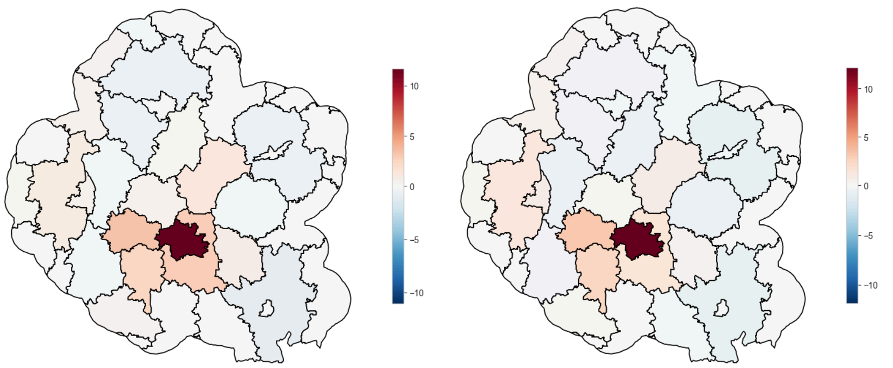


Fig. 11. Total Kilometers Travelled by Each Mode.

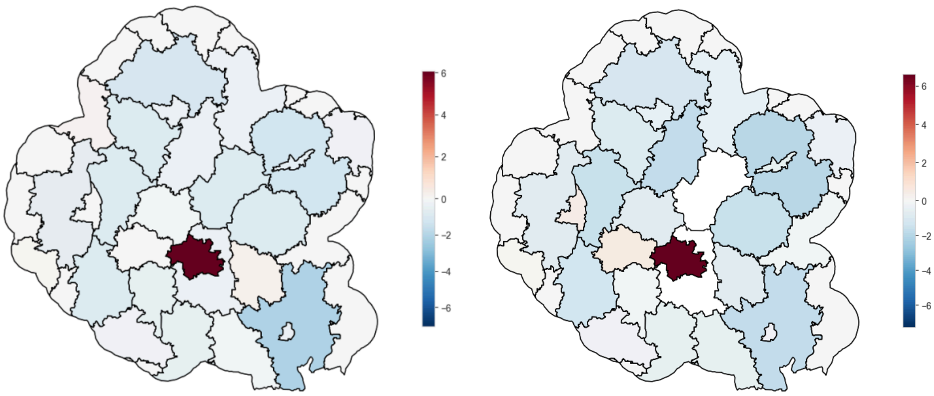
h. Emission Analysis

As a prominent greenhouse gas, CO_2 contributes greatly to global warming. Over 20% of global CO_2emissions come from the transportation sector (Kasliwal et al., 2019). Consequently, many studies opt to measure CO_2 levels when assessing transportation impacts. Another commonly studied air pollutant is NO_x (NO_x =NO + NO_2) (Hawkins et al., 2012). Not only does it contribute to greenhouse gas levels, but it also deteriorates air quality. NO_x can react with atmospheric moisture and other substances to generate nitric acid (HNO_3) and nitrous acid(HNO_2), leading to acid rain. This phenomenon subsequently acidifies soil and water bodies, damaging ecosystems and causing infrastructure decay. As a result, while various pollutants come from transportation, this project only focuses on CO_2 and NO_x emission quantities.



(a) Base vs OBUAM (b) Base vs KM++

Fig. 12. CO_2 Emission Changes between non-UAM Scenario and UAM Scenarios

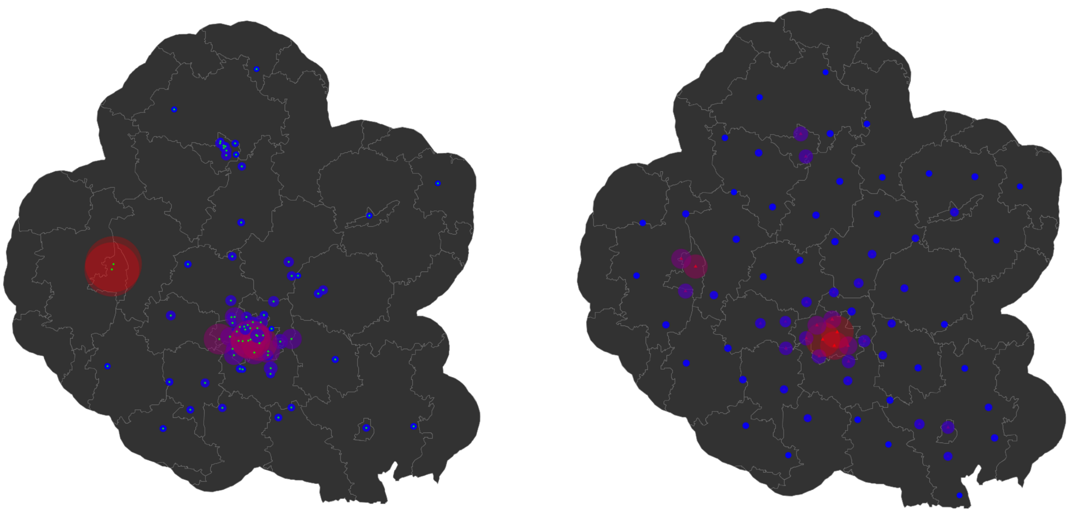


(a) Base vs OBUAM (b) Base vs KM++

Fig. 13. NO_x Emission Changes between non-UAM Scenario and UAM Scenarios

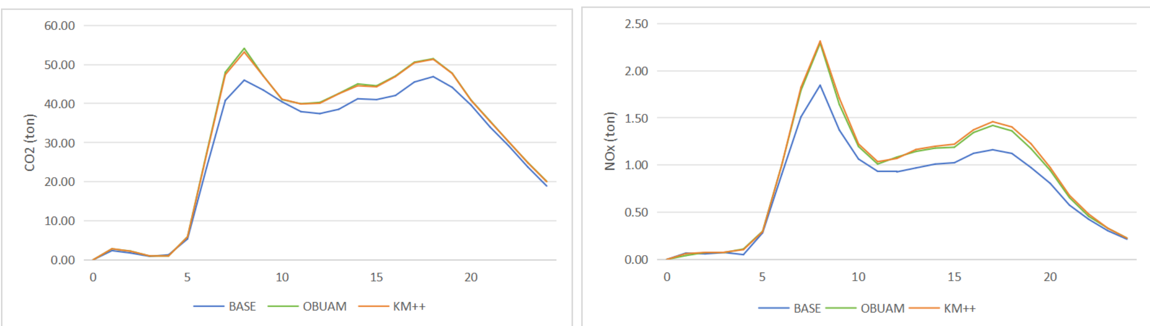
Fig. 12 and Fig. 13 show the emission changes of UAM scenarios compared to the base scenario across MMR. The orange indicates the increase in emission, and the blue indicates the decrease. Overall, the trends across most areas show a decrease or stability in emissions, with the notable exception of Munich, where both CO_2 and NOx emissions experienced a sharp increase.

On the one hand, Munich is one of the biggest cities in the south of Germany. There are indeed more car trips in urban areas than in rural areas. Meanwhile, although the station layout of KM++ is more even than that of the OBUAM scenario. Stations located in Munich areas are the most often used in both UAM scenarios (Fig. 14). Therefore, Munich became more attractive to travelers after introducing the UAM mode, which in turn results in an increasing number of car trips to access the Munich area, as well as more emissions.



(a) OBUAM (b) KM++

Fig. 14. Frequency of Trips from UAM Vertiports.



(a) CO_2 (b) NO_x

Fig. 15. Emission Changes Within 24 Hours.

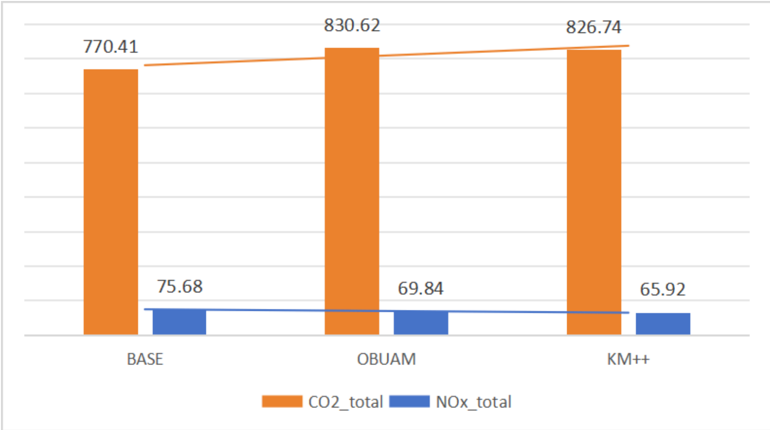


Fig. 16. Total Emission Changes (ton).

Fig. 15 illustrates the fluctuation in CO_2 and NO_x levels over 24 hours. Both emissions rose rapidly from 06:00 to 09:00, maintaining relatively elevated levels until approximately 17:00. Interestingly, the disparity between the two UAM scenarios is minimal. According to the overall data, the variance in CO_2 emissions between the OBUAM and KM++ scenarios is merely 3.88 tons, while for NO_x, it is 3.92 tons.

It seems both the OBUAM scenario and KM++ scenario exhibit adverse impacts on reducing CO_2 emissions. NO_x decrease but quite slightly, about 5.84 tons lower in OBUAM and 9.76 tons lower in KM++. However, as discussed above, the increase is mainly concentrated in Munich. The emissions in other places either stayed the same or decreased. The trend of emission increase directly matches the vehicle kilometers traveled shown in Fig. 11 and corresponds to the congestion depicted in Fig. 8(a). The congestion developed after UAM's introduction, which resulted in cars (especially as access and egress modes to UAM stations) accumulating more vehicle hours on the road. Unsurprisingly, drivers prefer to keep their engines turned on during the congestion. Therefore, total emission increases are witnessed in UAM scenarios. (Appendix i, j)

8. Discussion

The results from 7 (a, b, c) clearly show an improvement in terms of car reduction. We can also observe a slightly better performance of the OBUAM network than the KM++ network regarding mode share, passenger kilometers, and hours traveled. The result from 7(d) shows that the travel time savings from the OBUAM network outperform the KM++ network. This result contradicts the findings of Guo et al. (2023).

The congestion results from 7 (e, f) showed a drastic increase in vehicle congestion for both the UAM scenarios. Detailed investigation revealed a bottleneck in the UAM Vertiport Station Link. The station link is designed to serve both UAM and Cars and has significant traffic. And even though, the station link has a small length allowing faster “Link Leave” events, a vehicle can't leave the link in less than 1 second. This, coupled with the Congestion event handler’s limitation, may have produced such congestion results. In reality, there may be no congestion in the links at all.

From the emission analysis, we observed that both the UAM scenarios perform negatively regarding emission reduction. The results show that the most excess emissions were produced in Munich. The layout of the UAM Vertiport network and longer vehicle travel distance after the UAM introduction can explain this. Most of the UAM trips indeed originate and terminate in Munich. This attracts more access and egress car travel in Munich, exacerbating the congestion. But in the context of the other regions, emission conditions either improve or stay approximately the same due to the similar number of vehicles in all the scenarios.

9. Conclusion

The study found that UAM does reduce the original car trips but also produces nearly the same number of access and egress to UAM car trips. This resonates with the claim of Pukhova et al. (2021), who also suggested increased congestion in the Vertiport vicinity. Further research can focus on understanding and producing a solution for this problem. Furthermore, UAM has a positive environmental impact on most areas, so it is reasonable to say that UAM could be a reliable way to relieve environmental problems. Further research needs to pay more attention to UAM station layouts, which may affect people’s travel behavior greatly.

10. References

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Appendix

Location of Gitlab repository of Shahriar Iqbal Zame:
Main project: https://gitlab.lrz.de/ge96dav
PT2MATSim: https://github.com/shahriarzame/pt2matsim_2
MATSim UAM Extension: https://github.com/shahriarzame/MATSim-UAM

Location of Gitlab repository of Ying Huang:
MATSim Emission Extension: https://gitlab.lrz.de/ge94cay

If not stated otherwise, all paths to codes are based on Shahriar's Main Project.

a. OSM Filter with OSMIUM

```
osmium tags-filter "/mnt/c/Education/…/bayern-latest.osm.pbf" \
  w/highway=residential \
  w/highway=unclassified \
  w/highway=tertiary \
  w/highway=secondary \
  w/highway=primary \
  w/highway=motorway \
  w/highway=primary_link \
  w/highway=motorway_link \
  w/highway=trunk \
  w/highway=trunk_link \
  w/highway=secondary_link \
  w/highway=tertiary_link \
  w/highway=motorw

y_junction \
  -o "/mnt/c/Education/…/bayern-filtered.osm.pbf"
```

b. Network Extraction

Network extraction by an outer boundary

```
osmium extract -p obuam_Boundary.geojson  --strategy
complete_ways Bayern.osm.pbf  -o study_network.osm.pbf
```

c. List of PT Agencies

Agency_id,agency_name,agency_url,agency_timezone,agency_lang
195,Münchner Verkehrs- und Tarifverbund,https://www.bahn.de,Europe/Berlin,de
321,Stadtwerke München,https://www.bahn.de,Europe/Berlin,de
281,Augsburger Verkehrs- und Tarifverbund,https://www.bahn.de,Europe/Berlin,de
149,Augsburger Verkehrsgesellschaft,https://www.bahn.de,Europe/Berlin,de
17,Ingolstadt,https://www.bahn.de,Europe/Berlin,de
241,Landkreis Landsberg (Lech),https://www.bahn.de,Europe/Berlin,de
284,Landkreis Garmisch-Partenkirchen,https://www.bahn.de,Europe/Berlin,de
24,Stadtverkehr Rosenheim,https://www.bahn.de,Europe/Berlin,de
230,Landkreis Mühldorf,https://www.bahn.de,Europe/Berlin,de
208,Stadtwerke Landshut,https://www.bahn.de,Europe/Berlin,de
370,Landkreis Landshut,https://www.bahn.de,Europe/Berlin,de
221,DB RegioBus Bayern,https://www.bahn.de,Europe/Berlin,de
363,DB Regio AG Bayern,https://www.bahn.de,Europe/Berlin,de
341,BayernBahn Betriebs-GmbH,https://www.bahn.de,Europe/Berlin,de
252,Go-Ahead Bayern GmbH,https://www.bahn.de,Europe/Berlin,de

d. GTFS Filter code
src/main/python/gtfs/GTFS_FilteringBy_Agencies.py.

e. Demand Generator

Code location: "src/main/java/mmr_demand_gen/"
1. RunDemGen_FromABIT.java:
Function: Main class orchestrating the creation of Plans-Attributes XML, Household XML, and Vehicles XML.
2. CSV Parser Classes:
AbitLegsParser.java:
Function: Processes the legs.csv file from ABIT demand data.
PersonAttribute_Parser.java:
Function: Parses the pp.csv file (personal attributes) from the Synthetic Population data.

f. Config file:
The config file location:
original-input-data/version_3/output_config_base_nonUAM_SLURM.xml
The Java class to run the config location:

src/main/java/version_3/Run_version_3_loadConfig.java

g. Event Handlers:

Congestion Event Handler:
src/main/java/week10/CongestionDetectionEventHandler.java

Vehicle Distance Traveled Event Handler:
src/main/java/mmr_eventHandler/VehicleDistanceEventHandler.java

Runner Class: src/main/java/week10/RunEventsAnalysisExample.java

h. UAM Travel Time Calculator:

src/main/java/net/bhl/matsim/uam/analysis/traveltimes/RunCalculateUAMTravelTimes.java

i. Emission Calculation: From https://gitlab.lrz.de/ge94cay

UAM_emission/emissionCalculation

j. Emission Event Handler: From https://gitlab.lrz.de/ge94cay

UAM_emission/emissionAnaysis_time
UAM_emission/emissionAnalysis_spatial