Institute of Transportation Systems

Conversion of services on A65 to CAV

Project Report (V1.0)

Braunschweig, 01.09.2022
Alessa Isberner (DLR-TS)
Benedikt Scheier (DLR-TS)

Executive summary

A study with the microsimulation traffic simulation SUMO has been conducted to analyse traffic conditions on the A65 between the A6120 and the Inner Ring Rd. Several scenarios have been simulated to compare travel time in a baseline scenario representing todays traffic situation with two future scenarios where connected automated vehicles (CAV) replace conventional cars. In the first scenario all vehicles have been given CAV parameters and in the second a DRT service with CAV parameters has been installed in the neighbourhoods of Hawksworth and Horsforth. Due to the ride sharing concept in the DRT scenario 3% less vehicles are on the A65.
For the overall travel time on the A65 the DRT scenario shows the best results in the peak hour. The fact that there is slightly less traffic has a higher result than the CAV. During off-peak hours all three scenarios show similar results in terms of travel time.
For public transport on the other hand, the output of the 100% automated scenario show the best results. This can be linked to the better cooperation parameter of the CAV.

Aim and Research Question

Can connected automated vehicles in an on-demand service improve traffic and quality of life?
The following hypothesis have been analysed:

- Can an increase in vehicle occupancy reduce congestion and travel time?
- Can the accessability (compared to conventional public transport) in the study area be improved?
- Can a decrease in vehicle kilometers be seen and thus a reduction of emissions?
- Reduce land use for parking through a reduction of vehicles.
- Can the use of existing bus lanes on the A65 for shared vehicles lead to further reduce of congestion and journey times?

Additional research questions for the traffic flow on the A65 have been analysed in discussion with RGU and WYCA.

- What are the current travel times on the A65, measured for many smaller sections and how do they change in a scenario where all vehicles have CAV parameters and in a scenario where only DRT vehicles have CAV parameters?
- What are the effects on the existing public transport in all scenarios?

Methodolody

Traffic demand and infrastructure set up

14 traffic assignment zones (TAZ) have been created as Origin (A, B, D, E, h, H, I, J, K, L, I, II) and destination (h, H, K, L, M, I, J, III). Turning counts as well as count point data on the A65 from Leeds City council have been used to estimate Origin volumes from each TAZ into the simulated scenario as well as destination volumes leaving the corridor at the major junctions (compare Figure 1). Figure 1: Traffic Assignment Zones shows the location of the TAZ used for the simulation.

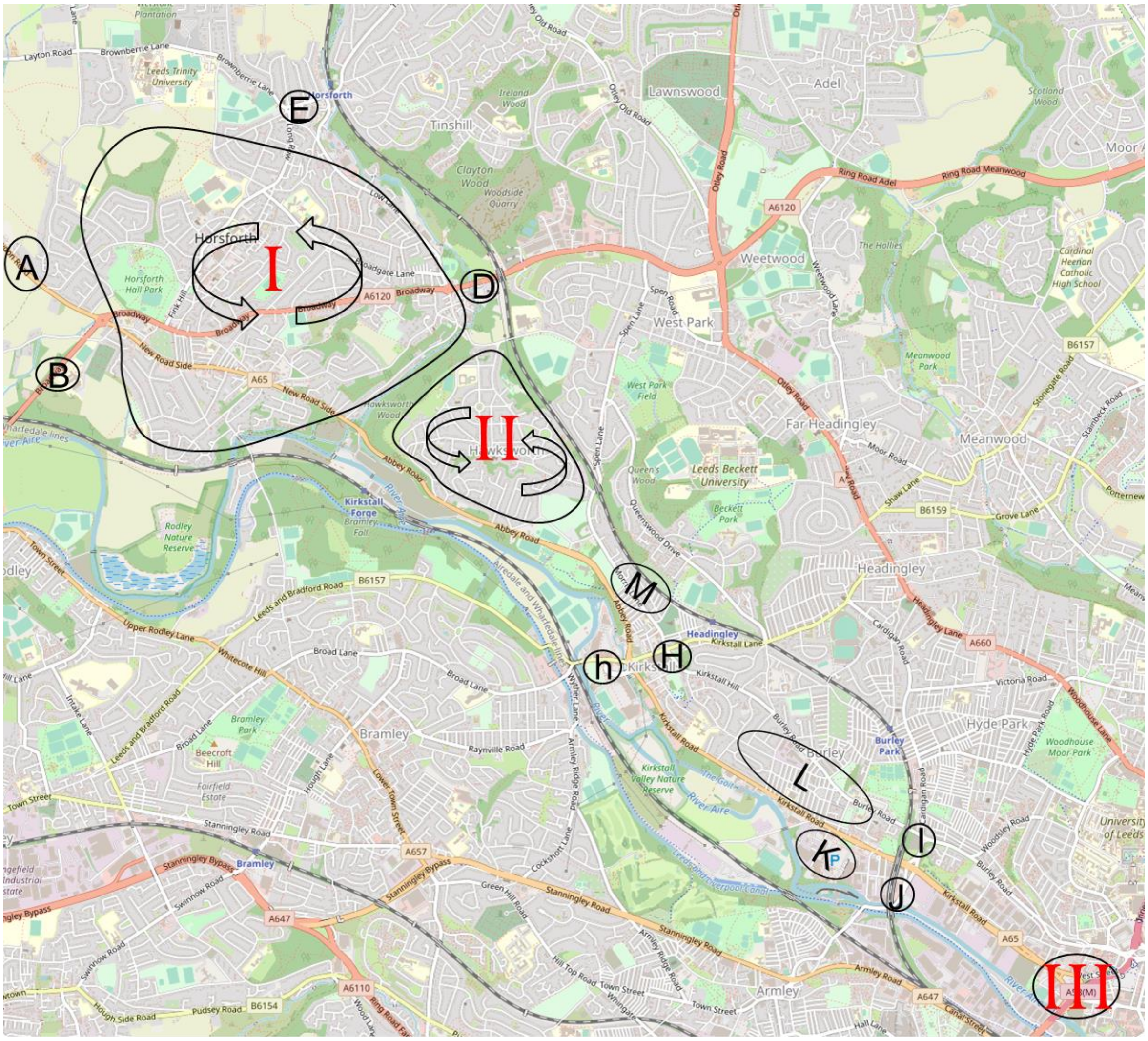

Figure 1: Traffic Assignment Zones

Traffic flows for the simulation have been generated in the form of individual trips. For each TAZ a number of edges has been selected as possible origins or destinations. For some TAZ such as I, II, L, M, K several edges have been selected. Other TAZ, namely A, B, E, D, h, H, I and J represent incoming or outgoing traffic into and from the scenario. Therefore, these TAZ only consist of one two edges, one origin and one destination edge. In a next step with the help of information from count point data origin and destination volumes have been estimated and iteratively improved over various simulation runs so that the traffic flows calculated from the OD matrices best match the count point data provided by Leeds city council.

This process to calibrate the traffic flows and verify the percentage of cars from each TAZ to the city centre (III) induction loops have been used at the locations where count point data from Leeds City council have been available to compare traffic flows at several points along the A65 (compare Figure 2). At the two major junctions in the scenario further induction loops have been created to also validate turning movements with data received from Leeds City council (compare Figure 3).

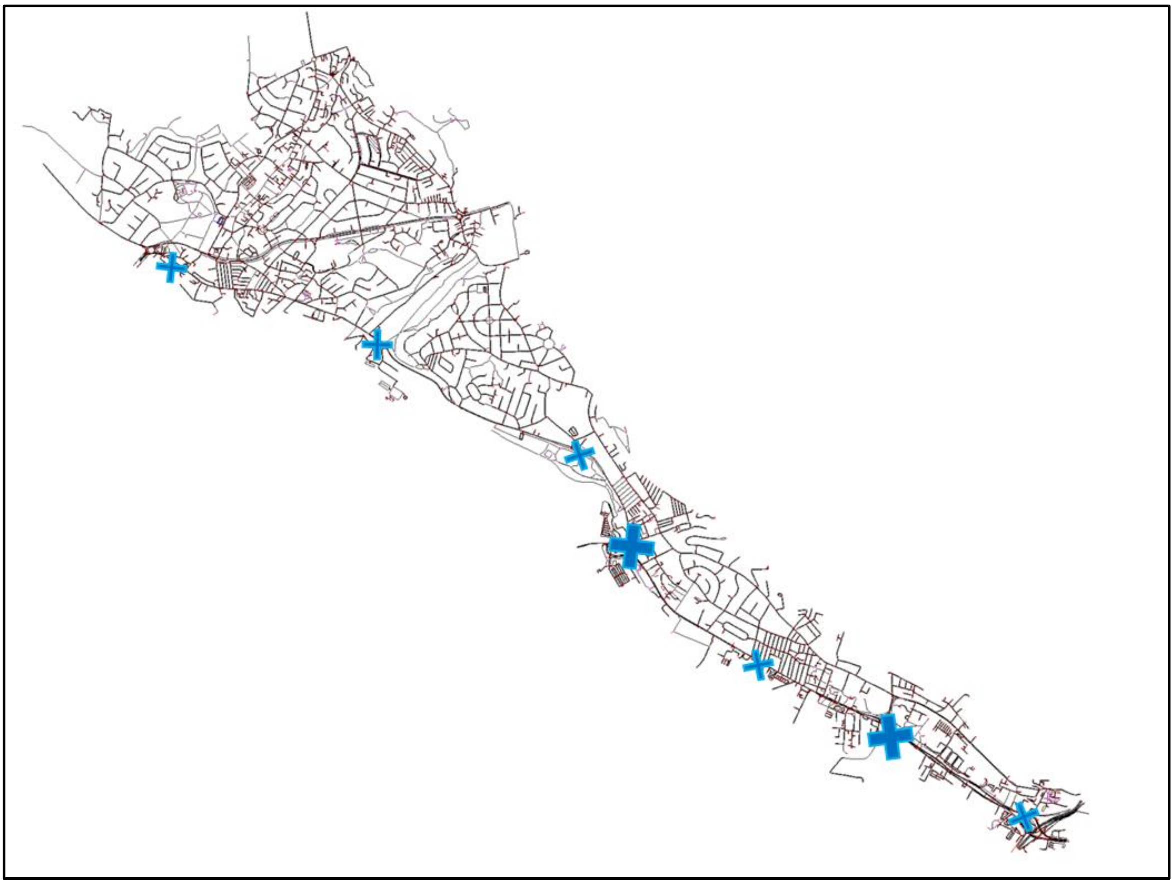

Figure 2: Induction Loops locations

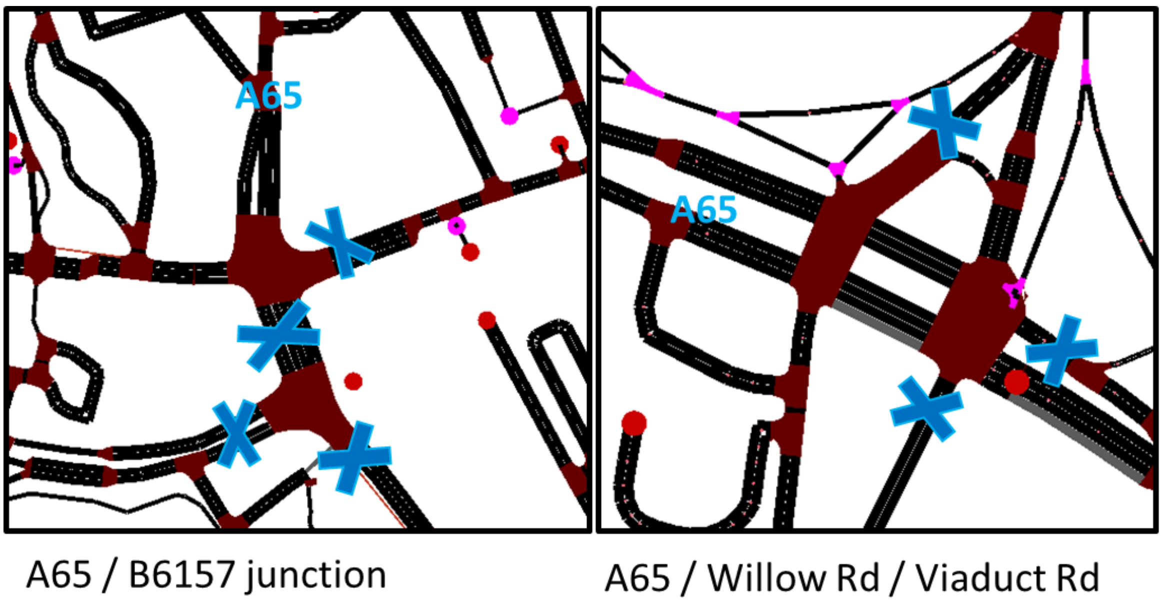

Figure 3: Induction Loops major junctions

Simulation output

The model that has been build simulates the traffic during the morning (6am-10am) including the peak hour (7am-8am) towards the city center. Figure 4 shows the whole network which has been modelled. Cars and busses driving towards the city center are colored by their speed (red = 0 mph; orange >0mph, yellow > 20mph, green > 30mph).

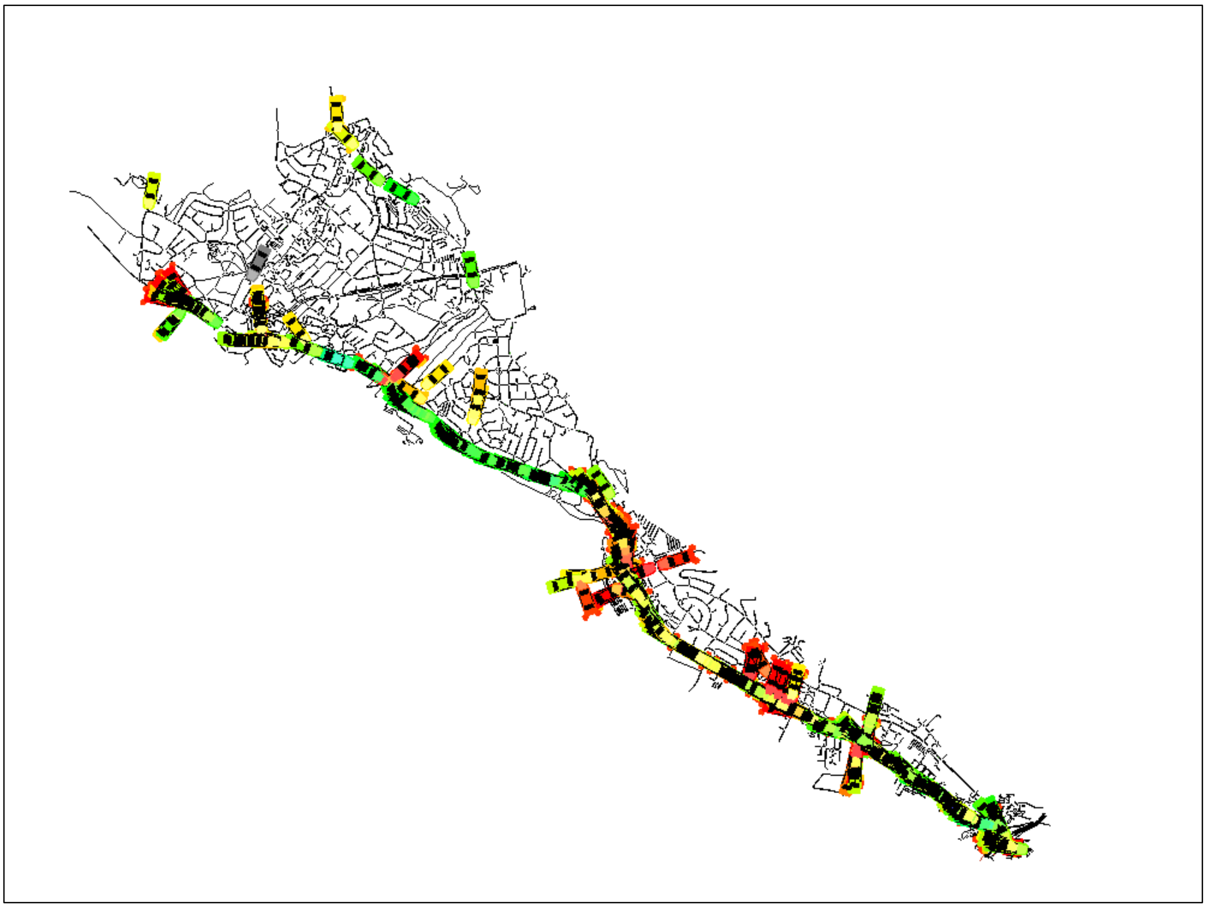

Figure 4: Leeds A65 scenario baseline

At seven points speed detectors have been added that record the time each vehicle passes these points (compare Figure 5). From this information, the average speed of all vehicles that pass between two of these points can be calculated. This was the average speed on the A65 can be obtained for roughly every mile section as well as the average speed for the whole simulated corridor length. As the allowed speed limited changes twice on the A65 within the simulated corridor, the speed detector sections are not distributed evenly but are located on the position of speed changes. This allows to be able to compare the allowed speed to the actual speed of the vehicles. For analysis purposes the sections have been numbered from A-F. Table 1 shows the length of each section.

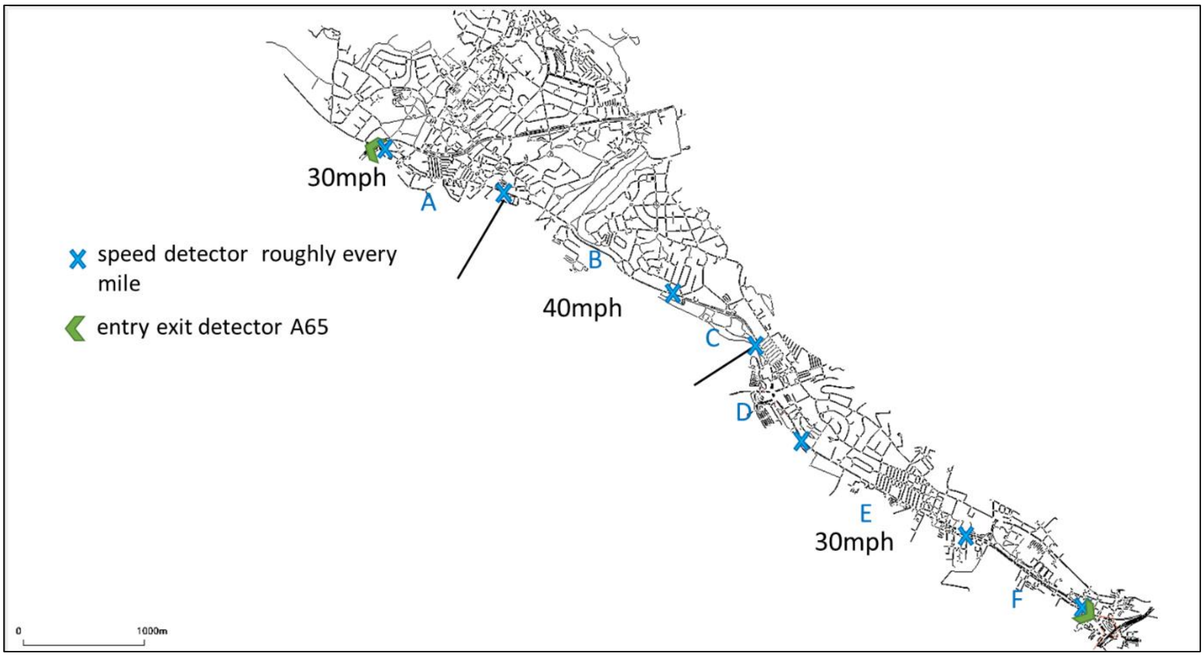

Figure 5: Speed detectors on the A65

Table 1: Speed detector distances

Section	Length in km	Length in miles	Allowed Speed in mph	Speed detector GEO-Coordinates
				53.834503, -1.650795
A	1,05	0,7	30	
				53.829174, -1.628760
B	1,78	1,1	40	
				53.821913, -1.607815
C	0,84	0,5	40	
				53.815746, -1.602128
D	0,94	0,6	30	
				53.810316, -1.594018
E	1,59	1,0	30	
				53.804356, -1.575298
F	1,3	0,8	30	
				53.798841, -1.562450
total	**7,5**	**4,7**		

Scenario development

Baseline scenario

The baseline is a model of the current traffic flows on the A65 between the A6120 and the Inner Ring Rd in Leeds. The baseline is used as a comparison for the automated scenario as well as the DRT scenario.

Automated vehicle scenario

In the automated scenario the driving parameter of the cars and busses are changed so they represent a possible behaviour of automated vehicles. As it is not yet known with what kind of driving behaviour automated vehicles will be equipped. Compared to the conventional car parameters, the automated vehicles have to drive strictly according to traffic regulations.
The parameters that can be varied in SUMO to simulate automated vehicles are the following: Speed factor, lcCooperative , LcAssertive, MinGap, tau and sigma. Table X gives an overview of the meaning of each of the variables [1].

Table 2: Automated vehicle variables

speedFactor	States the mean speed as well as the deviation, a min and a max value (mean, dev, min, man)
lcCooperative	Cooperation with other vehicles when changing lanes (lower value means lower cooperation
lcAssertive	Acceptance of smaller gaps for lane changing
minGap	Minimum Gap when standing in meter
Tau	Time headway to the car in front while driving in s
sigma	Deviation of a human driver from optimal driving (low numbers mean less deviation)

The following values have been used for the conventional and automated vehicles.

Table 3: Parameters for conventional and automated vehicles

	speedFactor	sigma	tau	minGap	lcCooperative	lcAssertive
Conventional vehicle	(1.1,0.1,0.8,1.4)	0.5	1.0	2.0	0.8	1.2
Automated vehicle	1.0	0	1.0	2.5	1.0	1.0

The trips that have been used in the automated scenario are identical with those in the baseline scenario.

DRT scenario

The DRT scenario in this report represents a scenario where less traffic drives along the A65 corridor. As 20% of the people from Hawksworth and Horsforth share rides into the city centre, less cars merge onto the A65 between Hawksworth Rd and Abbey Walk.

Table 4 shows the comparison of vehicles that pass each induction loop (compare Figure 2: Induction Loops locations) in the baseline scenario and the DRT scenario. There is about 3 % less traffic on the A65 south of Hawksworth and Horsforth.

Table 4: Comparison of traffic count baseline and DRT scenario

	7am	8am	9am
A65/A6120	100%	100%	100%
Hawksworth Rd	95%	100%	101%
Abbey Walk	93%	98%	99%
B6157 Kirkstall Ln (H)	93%	97%	97%
Savins Mill Way (h)	95%	96%	97%
Woodside View (L)	96%	97%	97%
Willow Rd	98%	97%	96%
Bingley St	98%	97%	96%

In the DRT scenarios, the DRT vehicles have the same parameters as the automated vehicles in scenario two. The cars however are parametrised as the conventional vehicles in the baseline scenario.
The DRT vehicles have a capacity for six people. In total 20 DRT vehicles are available. The DRT scenarios are run with two different routing algorithms. The greedy shared algorithm can only match up to two requests and is thus limited, does however have a very fast running time. The second algorithm used (DRTonline algorithm) need a much longer simulation time as it recalculates the routing of the trip requests every 60 seconds. It does however do a better job at matching several ride requests. As the vehicle capacity is limited to six, this algorithm matches up to six requests. All DRT vehicles start in a depot located in Horsforth park car park and drop off their passengers in the West street car park (compare Figure 6). The car park has been used as a drop off point because it is located at the end of the analysed corridor. In reality however, the passengers could be dropped of closer to the train station or city centre. As this is however not part of the simulated corridor, the car park has been used for the purpose of the analysis done.

Figure 6: Depot and drop-off location DRT scenario

As briefly described in chapter 3.1. the trips are calculated from the OD matrices. In the DRT scenario a percentage of 20% of the people from Hawksworth and Horsforth (TAZ I and II) are using the ride sharing service instead of their private car. To assign this new form of transport to different set of trips and therefore to sets of OD-matrices have to be created, one for the people that own a private car and one for those using the DRT service. The trip origin and destinations are the same as in the other scenarios.

Results

Travel times on the A65 have been analysed and compared for different scenarios. All results are shown in mph.

Results for the baseline scenario can be found in Table 5,Figure 6 and Table 7. Average speed results on the A65 per section are visualised in Figure 7.

Table 5: Average Speed baseline scenario

			Average speed						
Distance in miles	Allowed Speed	Section	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
0,7	30	A	25,6	24,7	24,8	24,7	24,9	24,7	25,4
1,1	40	B	29,6	28,4	28,8	29,3	28,9	28,9	30,1
0,5	40	C	30,3	29,1	20,7	23,1	28,2	29,7	30,2
0,6	30	D	18,9	18,4	13,8	13,2	19,5	20,6	21,4
1,0	30	E	20,5	17,0	15,2	13,1	15,4	17,1	21,5
0,8	30	F	22,3	22,1	21,7	22,2	22,2	22,2	23,2
4,7		total distance	23,2	21,9	19,8	18,1	21,2	21,5	23,3

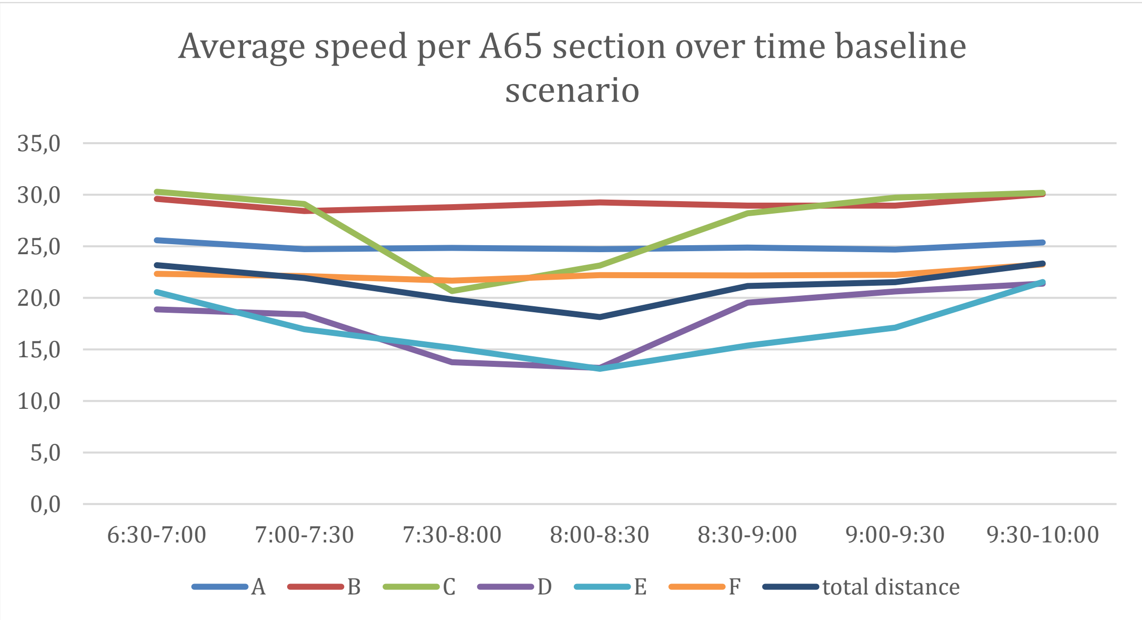

Figure 7: Average speed per A65 section over time baseline scenario

Table 6: Travel time total corridor baseline scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Travel time total distance in min	12,1	12,8	14,2	15,5	13,3	13,1	12,1

Table 7: Average speed and travel time Bus service baseline scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Bus average speed	15,3	15,3	14,3	14,4	14,5	16,0	16,0
duration total distance in min	18,4	18,4	19,7	19,6	19,4	17,5	17,6

Results for the automated scenario can be found in Table 8,

Table 9, Table 10. Average speed results on the A65 per section are visualised in Figure 8.

Table 8: Average Speed automated scenario

			Average Speed						
Distance in miles	Allowed Speed	Section	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
0,7	30	A	25,1	25,2	25,1	24,5	24,3	24,6	25,4
1,1	40	B	29,3	28,5	29,2	29,1	27,9	29,6	29,2
0,5	40	C	30,7	28,4	25,1	26,3	27,9	30,6	29,4
0,6	30	D	19,3	17,8	15,6	15,3	19,4	21,5	20,7
1,0	30	E	21,0	18,0	14,4	13,3	16,6	17,7	22,1
0,8	30	F	22,3	22,2	22,0	21,6	22,3	22,5	23,4
4,7		total distance	23,2	22,6	20,4	19,1	21,8	22,0	23,8

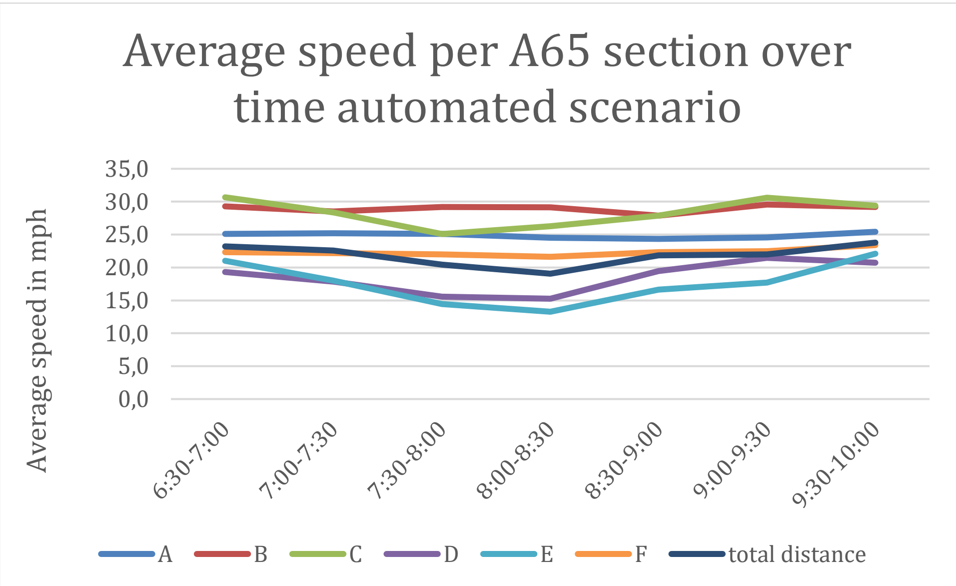

Figure 8: Average speed per A65 section over time automated scenario

Table 9: Travel time total corridor automated scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Travel time total distance in min	12,1	12,5	13,8	14,8	12,9	12,8	11,8

Table 10: Average speed and travel time Bus service automated scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Bus average speed	16,55	16,07	15,27	15,10	15,99	16,62	16,30
duration total distance in min	16,99	17,50	18,42	18,63	17,59	16,92	17,25

Results for the DRT scenario can be found in Table 11, Table 12 and Table 13.

Table 11: Average Speed DRT scenario

Distance in miles	Allowed Speed	Section	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
0,7	30	A	25,2	25,5	24,6	24,7	24,7	24,5	25,1
1,1	40	B	29,4	28,1	25,9	27,8	28,0	28,1	29,4
0,5	40	C	29,8	30,8	27,1	28,1	27,9	29,2	30,7
0,6	30	D	20,0	18,5	17,4	17,9	18,9	20,6	21,4
1,0	30	E	20,7	18,3	17,4	17,1	18,9	19,5	21,6
0,8	30	F	23,0	22,2	22,0	22,2	22,5	22,7	24,0
4,7		total distance	23,3	22,4	21,2	21,2	22,3	22,6	24,3

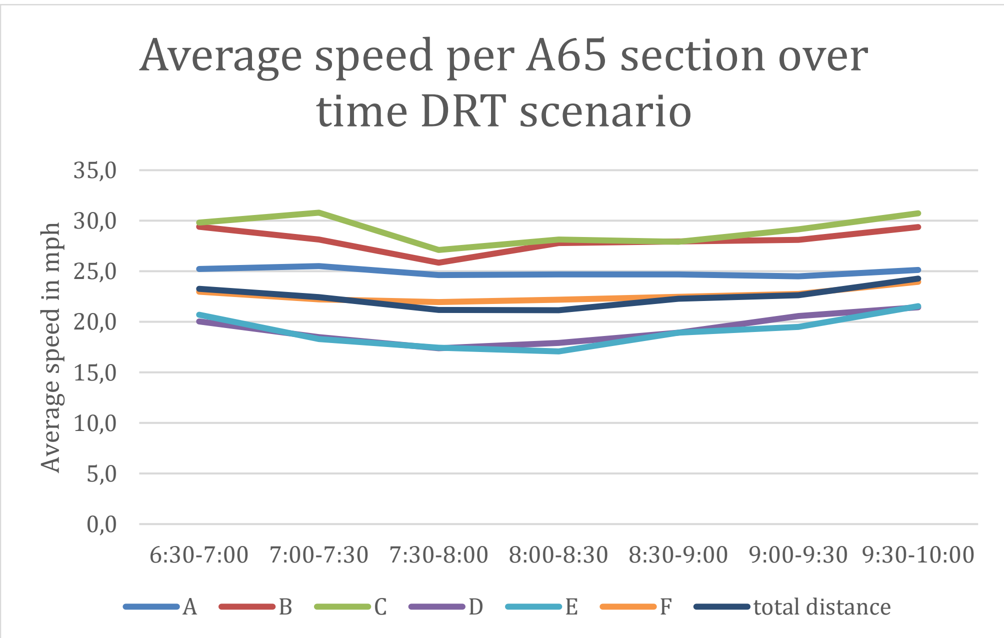

Figure 9: Average speed per A65 section over time DRT scenario

Table 12: Travel time total corridor DRT scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Travel time total distance in min	12,1	12,5	13,3	13,3	12,6	12,4	11,6

Table 13: Average speed and travel time Bus service DRT scenario

	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Bus average speed in mph	15,22	14,60	15,27	15,27	14,34	15,04	15,17
duration total distance in min	18,48	19,26	18,42	18,42	19,61	18,70	18,54

Travel time Discussion

Figure 10 shows the average speed over time for the total corridor for each of the three scenarios, Figure 11 a summary for each section of the A65.

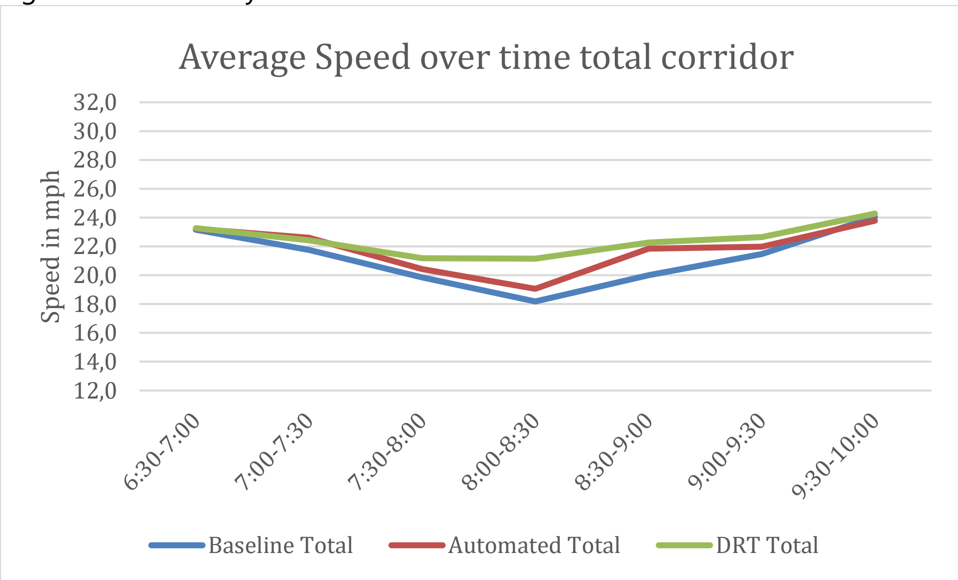

Figure 10: Average Speed over time scenario comparison total corridor

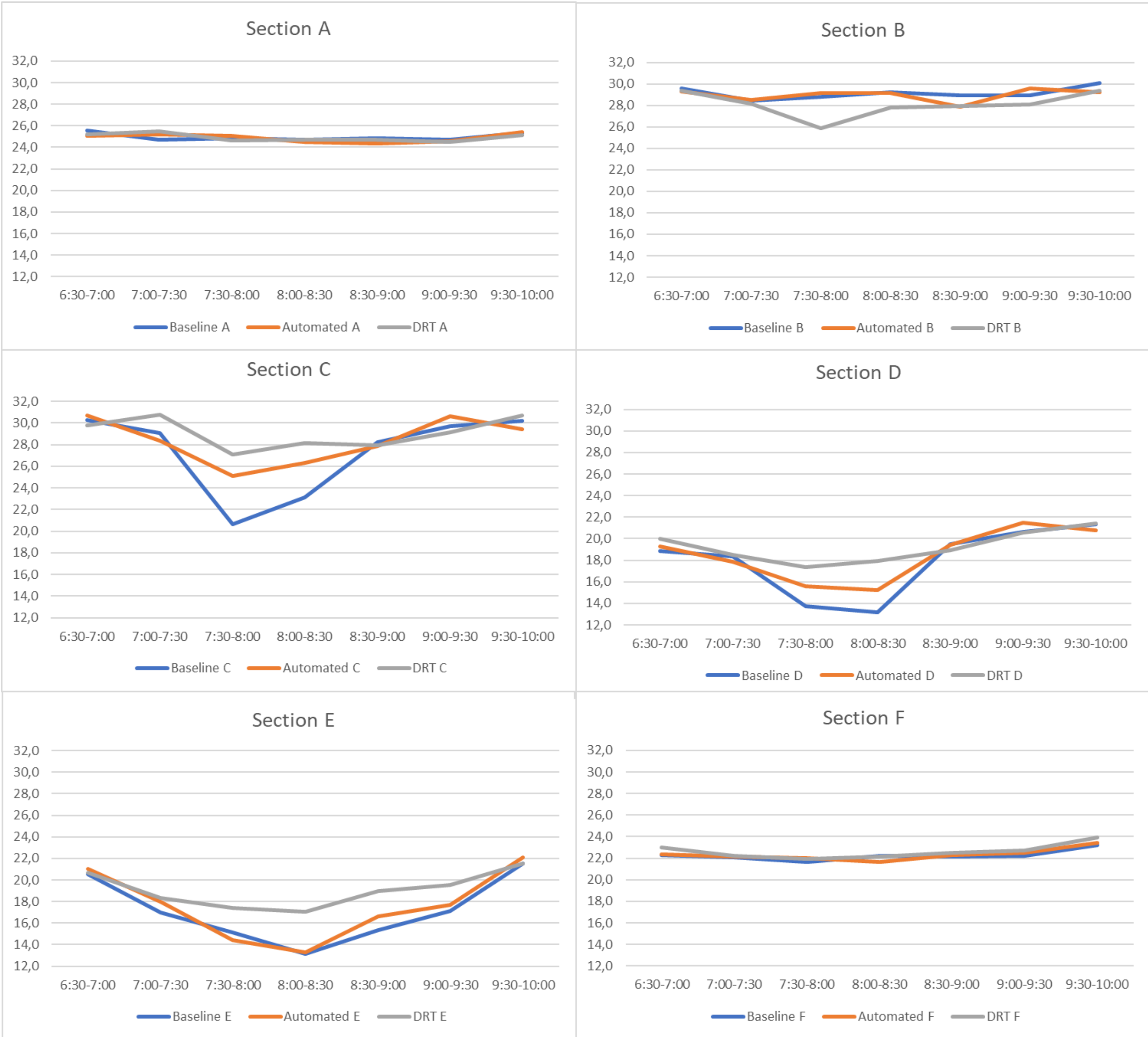

Figure 11: Average Speed over time scenario comparison for each section

All three scenarios show similar curves, with the lowest speed during the timeslot 8:00-8:30. In the DRT scenario the overall speed is highest. There reason here can be that there are fewer vehicles in the DRT scenario due to people traveling from Hawksworth and Horsforth sharing rides. This could imply that trying to reduce the number of vehicles even slightly (3% in the DRT scenario) has a higher effect for the average speed and thus travel time on the A65 than automation of cars.

When comparing the average speed of the buses driving along the A65 in the three scenarios (compare Figure 12), the simulation output shows the fastest results in the automated scenario. This can be among others due to the fact, that the cooperation with other vehicles is better parametrised for CAV than for human driven vehicles.
Even in the DRT scenario where the DRT vehicles are allowed to use the bus lane, the average speed and thus average travel time is better during peak hour than in the baseline scenario and on the same level during off-peak hour.

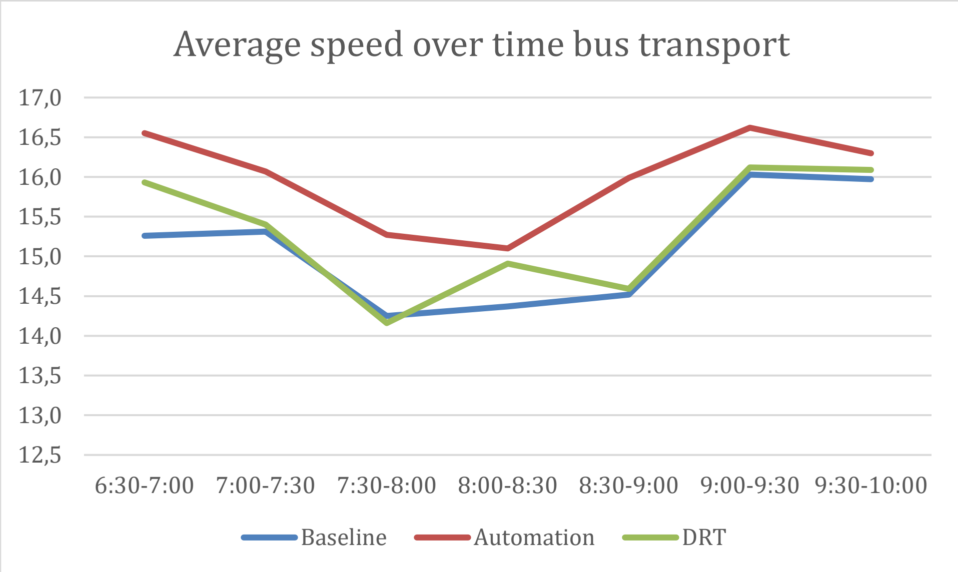

Figure 12: Average speed over time bus transport

DRT Results

Table 14 entails a summary of the main findings in the four DRT scenarios and the baseline scenario for comparison. Results are shown for the two different matching algorithms as well as a scenario with the availability of using the bus lanes for the DRT vehicles and without.

Table 14: DRT indicators overview

	Baseline	DRTgreedy_withBuslane	DRTgreedy_withoutBuslane	DRTonline_withBuslane	DRTonline_withoutBuslane
DRT routing algorithm	na	greedy shared	greedy shared	drt online	drt online
Number of DRT trips	-	311	311	316	306
Average route length Pax [mi]	4,28	4,25	4,26	5,51	5,58
Duration in-vehicle Pax [min]	12,8	11,4	12,0	14,9	15,35
Total route length vehicle [mi]	1.396	1.661	1.644	578	588
Pre-booking time [min]	-	16,52	16,95	10,22	10,78
Pooling factor	1,00	1,69	1,69	5,54	5,67
System efficiency	1,00	0,84	0,85	2,42	2,37

DRT Discussion

In the following, the analysis done according to the research questions is summarised.

<u>Hypothesis:</u> Increase vehicle occupancy → reduce congestion and travel time

Two different matching algorithms have been used
Greedy share algorithm – fast results; can match maximum of 2 rides
→Pooling factor 1,69
DRTonline algorithm – long simulation times, higher pooling factor possible
→Pooling factor 5,54

Table 15: Average travel time on the A65 in the DRT scenarios

	Average travel time on A65 [min]						
	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
Baseline scenario	12,1	12,8	14,2	15,5	13,3	13,1	12,1
DRTgreedy	12,2	12,7	13,3	13,5	12,8	12,4	11,7
Percentage difference	-1%	1%	7%	13%	4%	5%	3%
DRTonline	12,2	12,4	13,0	13,1	12,8	12,2	11,8
Percentage difference	-1%	3%	8%	15%	4%	7%	3%

As can be seen in Table 15: Average travel time on the A65 in the DRT scenarios shorter travel times by up to 15% (2,4 min) are visible during peak hour. During off-peak hours no big differences in travel time can be seen. The DRT algorithm used also shows no high effect on the travel time on the A65.

Hypothesis: Improve accessibility (compared to conventional public transport)
The average pre-booking time with the greedy algorithm is16,52 minutes with a standard deviation of 13,42min.
The average pre-booking time with drtonline algorithm is 10,22 minutes with a standard deviation of 12,63 minutes.
In comparison the service interval of the public transport service is 10-14 minutes.
The average walking time to pick up location is 1,57minutes and the average distance to pick up location 119metres.
The pre-booking time of the DRT service with 20 vehicles is higher than the current public transport offer. This can however be influenced by the number of DRT vehicles available.
The average walking distance can be improved in the DRT scenario as all public transport stops can be used as pick up points. This can also be varied to even more pick-up locations and thus even shorter walking times. In return this would however influence waiting time and ride distance and time.
The results in this case can vary depending on the chosen input parameters such as number of DRT vehicles, number of pick up points, matching algorithm, detour factors or the DRT vehicle size.

Hypothesis: Decrease vehicle kilometers → reduce emissions
This hypothesis is difficult to analyse in the chosen scenario set up as the traffic flow is only simulated in one direction with focus on the travel times on the A65. This leads to empty return

runs. Another point is the fact that the drop off is defined as the end of the simulated corridor and not a real individual destination for each person.

Total km baseline 1.396 mi
Total km DRTgreedy 1.644 mi
Total km DRTonline 588 mi

The results show however, that a high pooling factor can decrease the total kilometer driven (by 58% DRTonline scenario). If there is however only limited pooling, the total kilometer increases due to the empty return runs.

<u>Hypothesis</u>: Decrease number of vehicles → less parking spaces

In the Baseline scenario 10014 private cars are simulated in total, of which 1672 have their origin in Hawksworth and Horsforth.

In the on-Demand CAV scenario the number of private cars in Hawksworth and Horsforth is reduced to 1338. 20% of residential area demand uses On-Demand CAV which results in 334 possible trips done with 20 CAV-DRT.

This means that there are 314 vehicles less which can be converted into a reduction of necessary area for parking space of 3.611 m² when calculating with 2,3x5m per parking space.

<u>Hypothesis:</u> Use existing bus lanes → further reduce congestion and journey times

Table 16: Travel time comparison with and without use of the buslane for DRT vehicles

	Travel time on the A65						
	6:30-7:00	7:00-7:30	7:30-8:00	8:00-8:30	8:30-9:00	9:00-9:30	9:30-10:00
DRTonline with buslane	12,1	12,4	13,0	13,3	12,9	12,2	11,7
DRT online without buslane	12,2	12,4	13,0	13,1	12,8	12,2	11,8
Difference in travel time	**1%**	**0%**	**0%**	**-1%**	**-1%**	**0%**	**1%**
Greedy with buslane	12,1	12,5	13,3	13,3	12,6	12,4	11,6
Greedy without buslane	12,2	12,7	13,3	13,5	12,8	12,4	11,7
Difference in travel time	**1%**	**2%**	**0%**	**2%**	**1%**	**0%**	**1%**

No high visible differences through the use of the bus lanes for DRT vehicles can be seen in Table 16.

Conclusion

Several simulation runs on the A65 in Leeds between the A6120 and the Inner Ring Rd have been conducted. The results have been analysed according to changes in travel time.

No big differences could be seen during off peak hours. During peak hour the effects of having slightly less cars on the A65 (approx. 3%) due to the implemented DRT service in Hawksworth and Horsforth shows better results than the implementation of 100% CAV.

For the conventional PT however, the best results can be seen in the scenario with 100% CAV.

The analysis has solely been done on travel time. There are however many other factors which are relevant in a transport system.

In the DRT scenario the routing algorithm used had a big effect of the people using the DRT service, not however on the general traffic flow along the A65. Whereas a low pooling factor first increases the overall kilometres driven, a high pooling factor can decrease them and thus increase the system efficiency. Independent of the DRT parameter, getting more people to use other forms of transport than their private car decreases the necessary space for parking in residential areas.

However, the values used for the DRT scenario and to parametrise the CAV have been set but not varied. Sensitivity analysis could be done to improve the robustness of the results.

References

[1] German Aerospace Center (DLR) and others, “SUMO User Documentation,” 08 2022. [Online]. Available: https://sumo.dlr.de/docs/Definition_of_Vehicles%2C_Vehicle_Types%2C_and_Routes.html.