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September 2021

# Summaries of service and performance reports for DTU campus

Period covered: from April to November

Cold-start period: April

Shutting down period: November

Main operations period: from May to October

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## 1 Key Performance Indicator details

Most of the **Key Performance Indicators** (KPI) are computed on daily basis in local time. KPIs include each vehicle, and each test passenger smartphone with LINC App present in the range of 3 km from DTU Building 101. This data is collected to the LINC/IBM database which is designated to its storage, and can be accessed upon request contacting LINC project management.

## 2 LINC Bus – Passengers Interactions

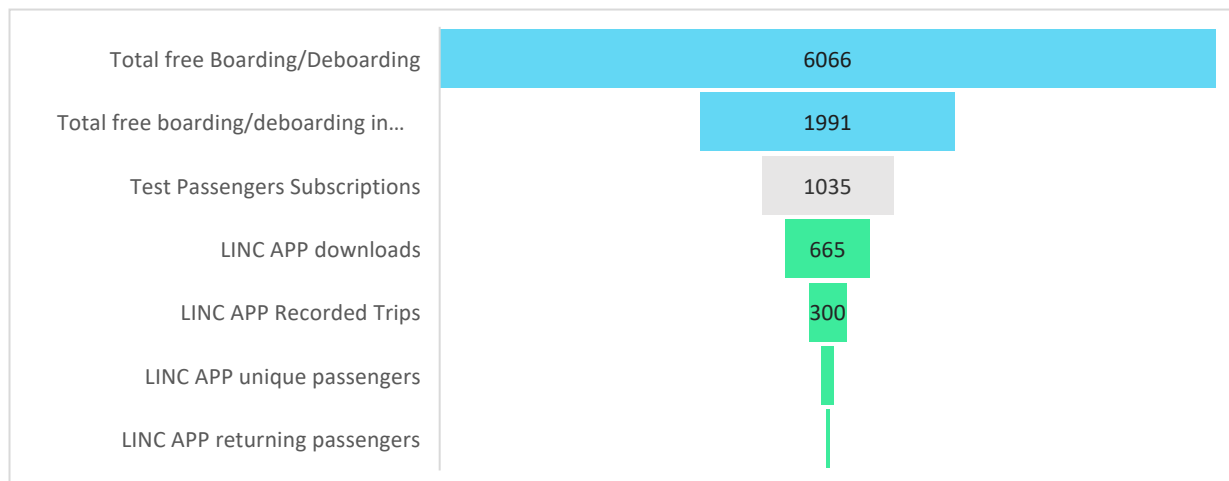


Figure 1. LINC –Passengers Interaction Funnel

Passengers’ population follows a funnel composition. From top to bottom (see Fig. 1 and Table 1):

- **Total free boarding/deboarding.** The top layer identifies free access passengers using LINC service without any need of subscription. For these we count boarding and deboarding. Counting is done daily in each vehicle by Nobina and with assistance from R2P<sup>1</sup>. Boarding and deboarding count does not identify unique users from returning users, nor personnel and stewards boarding and deboarding for any operational reason. People entering the bus for maintenance or for curiosity contribute to the total counts.
- **Total free boarding/deboarding in proximity of bus stops.** To remove the noise of personnel entering the bus for reasons such as maintenance, cleaning, and other interactions on the road, this layer identifies free boarding and deboarding only during operations time, e.g. no weekends, and only in proximity of the bus stops. Therefore, since R2P provides geolocation of each boarding and deboarding, we apply 10m range to these counts and 10m range to the bus stops. Then we pick the subset of counts within the area of interest defined by the intersection of these two ranges.

<sup>1</sup> R2P passenger counting @ <https://www.r2p.com/our-solutions/automatic-passenger-counting/>



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- **Test Passengers Subscriptions.** Next, we list the population subscribed within the LINC test passengers. This population does not use necessarily any of LINC Apps. However, LINC Apps require the subscription as LINC test passenger.
- **LINC App Downloads.** Next, we list the LINC app downloads. This population is not necessarily subscribed within the LINC test passengers. The download count includes individuals downloading the LINC App multiple times. This KPI includes both Apple iOS and Android smartphone users.
- **LINC App Recorded Trips.** Next, we list the trips recorded via LINC App. These trips are defined as the GPS segments with continuous logging, and time gap between points < 60 seconds, presenting an independent measure of Bluetooth Signal Strength > -60 decibel
- **LINC App Unique Passengers.** Next, we list LINC unique passengers tracked via LINC App. This is the population traceable on buses through the LINC smartphone sensing platform. For this population is possible to count trips, unique passengers and returning passengers.
- **LINC App Returning Passengers.** The bottom layer identifies LINC returning test passengers, which used the LINC shuttles more than once.

Table 1 LINC Passengers Interaction Funnel (May-October)

Total free Boarding/Deboarding	6066	100,00%
Total free boarding/deboarding in proximity of bus stops	1991	32,82%
Test Passengers Subscriptions	1035	17,06%
LINC APP downloads	665**	10,96%
LINC APP Recorded Trips	300	4,95%
LINC APP unique passengers	97	1,60%
LINC APP returning passengers	34	0,56%

\*\* 234 Android, 431 iOS

### 3 Free boarding Deboarding Vs. LINC App Passengers

Fig. 2 depicts the interactions between passengers and LINC buses. Both LINC App recorded trips and free boarding/deboarding counts in proximity of the bus stops show a usage consistent with the campus activities—which is not intense during summer vacations in July. These two perspectives present a positive



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correlation (0,61), and activity peaks consistent with summer vacations in July, where DTU activities on campus are limited.

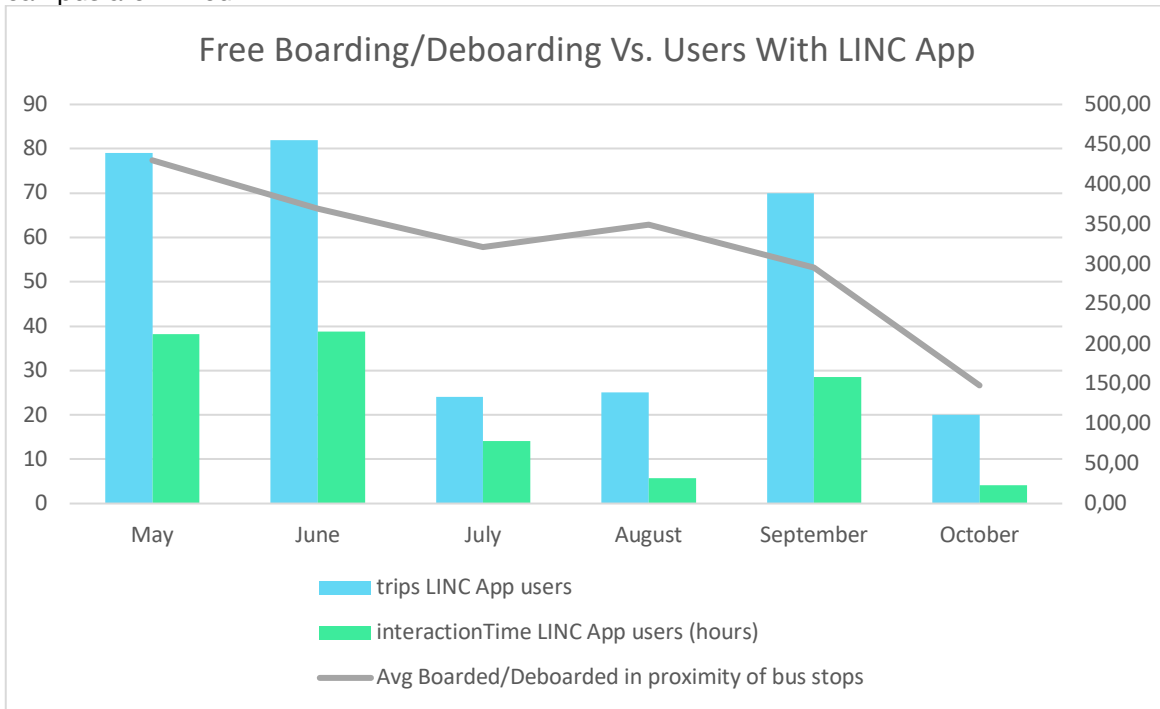


Figure 2. Passengers – LINC interactions split by month.

Table 2. Passengers – LINC interactions split by month.

Feature		May	June	July	August	September	October
Count from test passengers using LINC App	Trips ***	79	82	24	25	70	20
	Returning users	9	14	5	7	11	5
	Unique users	22	29	7	13	20	15
	interactionTime (hours)	38,27	38,74	14,04	5,65	28,59	4,19
Count from device installed on Buses	Sum of Boarding in proximity of bus stops	398	358	325	317	282	153
	Sum of Deboarding in proximity of bus stops	462	381	317	382	310	143
	Avg Boarding/Deboarding in proximity of bus stops ***	430	370	321	350	296	148
	Std Boarded/Deboarded in proximity of bus stops	45	16	6	46	20	7



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## 4 Bus Operating Hours

Operating hours is registered and summed by Nobina and is included in the Summaries of service and performance reports of DTU. Service level of operation is measured by Nobina on a monthly level. Fig. 3 depicts the comparison between LINC Target, Planned, Operations and Operators hours. Unlike Tab. 3, the account in Fig. 3 includes the service cold start and the shutdown periods. We see that Planned hours are approximately 33% more than Operation hours. This indicates that the LINC service has been subject to challenges preventing to effectively turn the plans into operations. Operators' hours reflect the same trend.

- **Time in operation:** Hours in operation at DTU site.
- **Planned hours:** Hours of operations planned.
- **LINC Target hours:** Hours of operations to be delivered as for LINC project agreement.
- **Operator hours:** Hours of accounted for personnel attached to LINC operations at DTU.
- **Service level of operation:** comparing completed bus operation in relation to scheduled.
- **Difference between planned end effective operations:** comparing completed bus operation in relation to the plan.

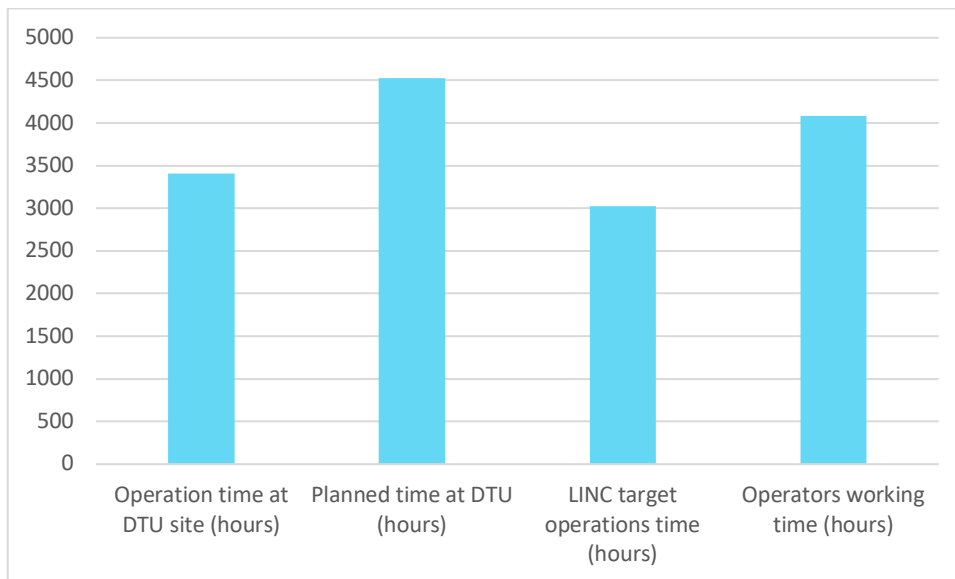


Figure 3. Total operation hours including cold start (April) and shut down (November) periods.



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Table 3. Total operation hours excluding cold start (April) and shut down (November) periods.

Feature	May	June	July	August	September	October
Hours in operation at DTU site (hours)	385,00	501,00	455,00	531,00	399,00	503,00
Planned hours of DTU	374,40	608,77	713,45	733,92	713,42	713,42
LINC target hours	380,63	440,73	440,73	440,73	440,73	420,70
Operator hours	467,00	741,80	690,80	491,53	379,00	645,00
Difference between Planned and effective **	-10,60	107,77	258,45	202,92	314,42	210,42
Service level of operation Planned vs. Operation hours	102,75	82,35	63,72	72,40	55,95	70,45
Service level of operation according to LINC target	1,01	1,14	1,03	1,21	0,91	1,19

## 5 Emergency Stops, Autonomous driving disconnection and Accidents

The following Fig. 4 and 5 show the breakdown of the reasons for autonomous driving disconnection for the three buses, organized by month. Fig. 4 shows the total counts, while Fig. 5 shows the counts per 100km. In October, Fig. 4 shows a consistent increase of disconnections due to obstacles. In the same period the personnel reported problems with the leaves falling from the trees, triggering buses emergency stops. In July, August and September, Fig. 5 shows anomalous platform and manual disconnections per 100km. In the same period, only two buses could operate and the third had mechanical problems. The anomaly is consistent with the very high number of disconnections that the bus under maintenance recorded in the short test trips, necessary to find and fix the problem.



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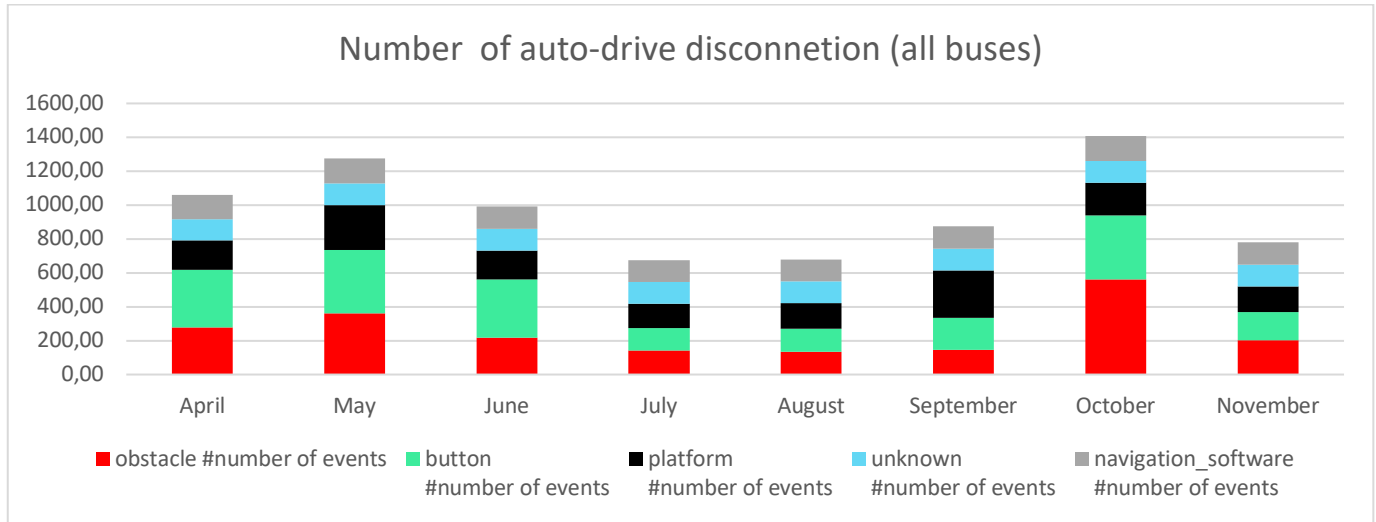


Figure 4. Disengagement Reason whenever there is a problem with the vehicle – number of events

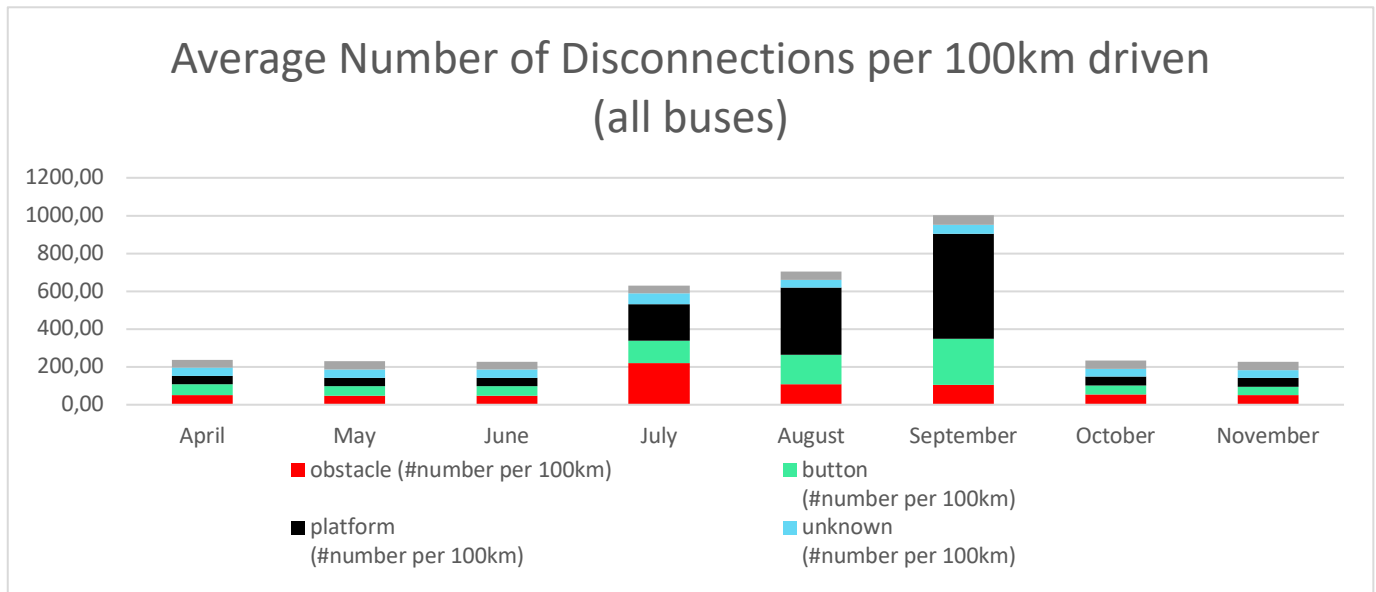


Figure 5. Disengagement Reason whenever there is a problem with the vehicle – Number of events per 100km of operations

- **Obstacle:** Obstacle detection.
- **Button:** Button pressed by operator
- **Platform:** Platform problem
- **Unknown:** Unknown cause.
- **Navigation Software:** Navigation software disengagement.





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- **Total disentanglements:** Sum of all disentanglements.
- **Accidents with other vehicles on the road:** Number of accidents with any vehicle or pedestrian circulating on the road.
- **Reported Incidents with injured passenger:** Number of incidents involving any type of injuries and passengers.

Table 4. Number of emergencies stops, by cause and by month

Feature	May	June	July	August	September	October
Obstacle #number of events	362	219	142	133	147	563
Button #number of events	372	342	134	137	187	375
Platform #number of events	264	169	140	152	281	193
Unknown #number of events	130	129	129	128	129	130
Navigation software #number of events	146	133	128	128	130	146
Total disentanglements #number of events **	1274	992	673	678	874	1407

Table 5. Number of emergencies stops per 100 km, by cause and by month

Feature	May	June	July	August	September	October
Obstacle (#average per 100km)	49	47	220	107	107	54
Button (#average per 100km)	49	52	118	159	241	49
Platform (#average per 100km)	46	44	194	352	558	44
Unknown (#average per 100km)	43	43	55	43	46	43
Navigation software (#average per 100km)	43	43	43	43	49	43
Total disentanglements (#average per 100km) *	229	228	630	703	1001	233

Table 6. Accidents on the road and incidents with injuries

Accidents with other vehicles on the road	0,00	0,00	0,00	0,00	0,00	0,00
Reported Incidents whith injured passengers	0,00	2,00	0,00	0,00	0,00	0,00

Table 6 reports 2 accidents (material and personal) injuries or near misses:

8/6-2021 (11:45): A shuttle performs a sudden emergency stop, possibly due to a bird triggering sensor. This result in an operator falling inside the shuttle. The operator hits his chest on a seat and also experience injury to his left arm and leg, resulting in minor bodily injury (bruises etc.).



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30/6-2021 (between 13:15 – 13:30): Shuttle 055 performs a sudden emergency stop due to heavy rain triggering sensors. This result in a customer falling inside the shuttle. No body injury is reported.

No accidents with other vehicles or pedestrians on the road were recorded.

## 6 Buses operations main features

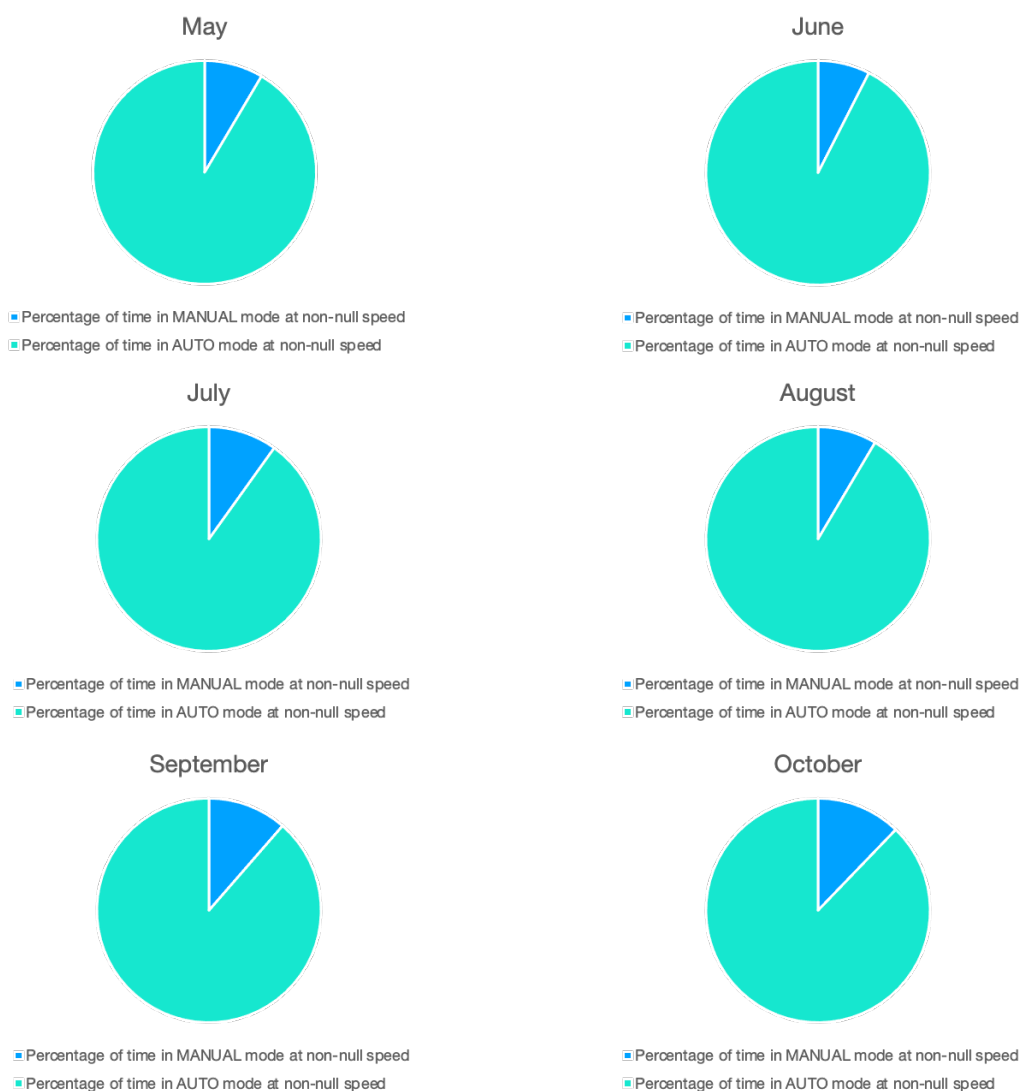


Figure 6. Percentage of auto and manual drive mode, by month.



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- **Average Emergency Stops in AUTO:** Number of emergency stop events occurring in AUTO mode when the vehicle speed is greater than 0km/h.
- **Average Commercial Speed:** Average speed of the vehicle in km/h when the doors are closed.
- **Average Speed:** Average speed of the vehicle in km/h.
- **Max Speed in AUTO:** Maximum speed of the vehicle reached in AUTO mode in km/h.
- **Driving Mode Split:** Percentage of time for each driving mode (AUTO or MANUAL) regarding the vehicle's connection time.
- **Driving Mode Split at non-null Speed:** Percentage of time for each driving mode (AUTO or MANUAL) at non-null speed regarding the vehicle's connection time.
- **Gross Distance Covered:** Km driven by bus, total, and average per bus.

Table 7. Buses operations main features

Feature	May	June	July	August	September	October
Average emergency stops in AUTO mode per day	11,10	8,40	7,60	9,20	5,30	14,40
Average speed per day (km/h)	5,20	5,40	5,10	4,40	4,10	4,30
Average commercial speed per day (km/h)	5,60	5,90	5,70	5,00	4,70	4,70
Maximum speed in AUTO mode (km/h)	15,20	15,30	15,30	15,30	15,30	15,70
Percentage of time in AUTO mode	75,60	78,20	77,60	67,60	65,60	67,20
Percentage of time in AUTO mode at non-null speed	91,50	92,50	90,10	88,60	91,00	87,80
Gross Distance Covered BUS 053 (km)	801	1696	1352	578	1517	882
Gross Distance Covered BUS 055 (km)	817	1504	2047	683	726	1235
Gross Distance Covered BUS 056 (km)	1308	784	3	3	10	1268
Total Gross Distance Covered (km)	2927	3984	3401	1264	2253	3385
Averag Gross Distance Covered per bus (km) *	976	1328	1134	421	751	1128

## 7 Bus consumption features

- **Battery Consumption:** Battery consumption of the vehicle in kWh.
- **Battery temperature:** Average battery temperature in °C.
- **Cabin temperature:** Average cabin temperature in °C.
- **Outside temperature:** Average outside temperature in °C.
- **Average Ramp Activations:** Number of engagements of ramp for wheelchair.



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Table 8. Bus consumption features

Feature	May	June	July	August	September	October
Average battery consumption per day (kWh)	3,00	14,50	16,30	9,20	8,20	15,40
Average battery temperature (°C)	17,10	26,40	29,10	22,50	23,30	17,90
Average cabin temperature (°C)	26,20	18,00	19,30	19,90	20,70	30,20
Average outside temperature (°C)	18,60	25,60	27,20	22,50	22,50	18,10
Average ramp activations per day	0,10	0,00	0,00	0,10	0,00	0,20