CIVITAS ECCENTRIC 7.4 NIGHT DELIVERY WITH CLEAN AND SILENT VEHICLES

TRANSPORT EFFICIENCY EVALUATION

FINAL REPORT

2019-09-09

LOTS GROUP

Executive summary

This evaluation report was produced following an experimental test taking part during eight months between January-August 2019. Academia, municipal and commercial actors came together to explore future alternatives for urban mobility in the city of Stockholm. The project was executed under the framework of Civitas Eccentric, which is a partly EU financed network between European cities dedicated to achieving cleaner and better cities in Europe and beyond.

The mission was to measure the impacts of replacing daytime diesel truck deliveries of goods in urban areas with nightly deliveries, called “off-peak deliveries”. This was done using clean and silent vehicles able to run on electricity. The project partners were HAVI Logistics, McDonald’s, KTH and the Transport Department of Stockholm. LOTS Group was contracted to measure the impact of the project.

The test took place using six centrally located McDonald’s restaurants as delivery points, starting from a warehouse in the outskirts of Stockholm operated by transport company HAVI Logistics.

The test vehicle, called PHEV, was supplied by Scania. The acronym stands for plugin hybrid electric vehicle. It used HVO as source of energy when driving outside the inner-city. HVO is an acronym for hydrotreated vegetable oil and is a form of renewable diesel produced from both animal and vegetable oils and fats. The PHEV switched to its electric engine when entering a pre-determined zone border to the inner-city. The other HAVI owned diesel trucks were used as reference vehicles to create the comparison.

The result of the evaluation shows potential of remarkable transport efficiencies and societal benefits when utilizing off-peak deliveries. The average time saved using off-peak deliveries was 30% compared to the average daytime equivalent transport route. When Comparing off-peak deliveries to different daytime intervals, cycle times reductions went as high as 38% when compared to daytime routes between 7 a.m. – 12 a.m.

CO_2 emissions for off-peak deliveries using the PHEV were on average 44% less than the reference vehicles. When comparing CO_2 emissions between the two types of vehicles outside of the inner-city, a reduction of 20.4% was still achieved. Every transport route using the PHEV saved on average 82 kg of CO_2 emissions. Reduction of particle emissions like NOx went up to 85% on an average transport route.

Interviews with the test driver showed that the working conditions were satisfying. The driver also experienced a simpler environment to operate in with higher degree of comfort and less risk of congestion and accidents.

LOTS GROUP

Table of contents

1 Introduction

1.1 Background

The city of Stockholm is participating in the EU project Civitas Eccentric, through its transport department and the environment and health department. Civitas Eccentric is designed to test, develop and share knowledge about innovate solutions for sustainable mobility in urban centers. It is a collaboration between cities, academia, business and policy makers.

One of the initiatives in Stockholm is “Measure 7.4 Night delivery with clean and silent vehicles” which the transport department oversees, together with KTH. This measure aims at building on an earlier conducted pilot study for nightly deliveries (Off Peak City Distribution). A procurement process for which KTH was responsible, have resulted in a consortium consisting of Scania, HAVI Logistics and McDonald’s being named the winners. The project is a transport assignment that will run during 2019 and test the transport efficiency of running deliveries to restaurants at night in the inner city of Stockholm, using a hybrid vehicle that partly run on electricity.

LOTS Group has been contracted to evaluate the transport efficiency of “Civitas Eccentric 7.4 – Night delivery with clean and silent vehicles”. This report is produced to act as a quantitative and qualitative evaluation which can be used for further initiatives within Civitas in other cities and act as decision support for other interested parties going forward with trials including one of the components of this project.

LOTS Group, a subsidiary of Scania and the Volkswagen Group, is both a transport company and a professional advisor to actors in the transport industry. LOTS Group supports its clients in identifying and realizing improvement opportunities in their logistic setup, whether it is about reducing CO_2 emissions or increasing operating profits. Utilizing its own developed visual transport management system, transport flows can be followed in real-time. This unlocks insights where better working methods can be found, and smart proactive decisions can be made.

1.2 Definitions

In order to make the report easier to read, central acronyms and abbreviations are listed in table 1. Definition of key concepts:

Table 1. Definition of key concepts	
Term	**Explanation**
PHEV	Plug-in hybrid electric vehicle, the test vehicle in focus of the evaluation
Geofence zone	A defined virtual perimeter for a real-world geographic area, used to capture information signals sent within the borders of the zone
Total transport route	The full length of the transport assignment including deliveries to all six restaurants and driving back to the warehouse
Cycle time	The total time it takes to carry out a described transport assignment from starting point, to delivery and then returning to the starting point
Visit ID	A unique identification number created when entering a geofence zone. The number is used as a key to find relevant information of a vehicle's positioning and activities within the geofence zone.
LTM	LOTS proprietary transport monitoring system. This is the software in which geofence zones are created and information is sorted through.
HVO	Hydrotreated Vegetable Oil, a renewable fuel that is produced from vegetable and animal fats and oils. It's compatible with all major truck manufacturers diesel engines.

1.3 Scope of transport assignment

The transport assignment consists of deliveries of food and daily consumables to six (6) McDonald's restaurants located in the inner city of Stockholm. The warehouse facility is operated by HAVI Logistics. The addresses are outlined in table 2. Transport points:

Table 2. Transport points	
Description	**Address**
McDonald's Folkungagatan	Folkungagatan 50, 116 22 Stockholm
McDonald's Sveavägen	Sveavägen 71, 113 50 Stockholm
McDonald's Götgatan	Götgatan 91, 116 62 Stockholm
McDonald's Liljeholmen	Liljeholmstorget 94, 117 61 Stockholm
McDonald's Hornstull	Hornsgatan 88, 118 21 Stockholm
McDonald's Slussen	Katarinavägen 1-3, 116 45 Stockholm
HAVI Warehouse	Tuna gårdsväg 4, 143 47 Tumba

The test period for which data has been collected is mid-January 2019 to late-August 2019. With this time period it was possible to measure the vehicles' performance in winter, spring and summer climate which gives a fair view of the annualized performance. The deliveries were scheduled twice a week, Sunday nights to Monday mornings and Tuesday night to

Wednesday mornings. Starting from 2019-02-21, an additional delivery was added on Thursday nights to Friday mornings to fully service the need of resupplying the restaurants. All deliveries are performed in the same order to the restaurants. The transport schedule is described in Annex (6.1).

The PHEV has capacity to deliver goods to two restaurants before it needs to return to the warehouse to resupply. Each section of the total route is therefore split into section A, B or C as listed in Annex (6.1). These parts of the route are both compared collectively and separately to create a more granular analysis.

The reference vehicles are presented in table “Reference vehicles”. These are the HAVI owned trucks that are used to compare against the PHEV:

Table 3. Reference vehicles

Registration number	Specification	Euro class	Fuel used	Horse power
RBB753	Scania P410 4x2	Euro VI	HVO	411
OGC715	Scania P410 6x2	Euro VI	HVO	411
DSC670	Scania P320 4x2	Euro V	HVO	230
XHE037	Scania P360 6x2	Euro VI	HVO	360

2 Scope of evaluation

2.1 KPIs

In order to comply with the Civitas standardized framework of collecting data and enabling international coordination, LOTS have been asked to focus the evaluation on the following KPIs, outlined in table “Requested KPIs to evaluate”:

Table 4. Requested KPIs to evaluate				
Impact	Transport efficiency	Transport efficiency	Transport efficiency	Transport Emissions
Indicator name	Vehicle-kilometer travelled	Accuracy of time keeping	Peak/off-peak travel time difference	Emission difference
Type	KPI	KPI	KPI	KPI
Category	Transport System	Transport system	Transport system	Environment
Subcategory	General	Public Transport	Public Transport	Pollution and nuisance
Aspect	Total travel	Service reliability	Congestion levels	Emissions
Definition	Potential km saved by using night hours	On time deliveries according to pre-planned route	Potential time savings by using night hours	Existing emissions levels compared to off-peak situation

Following a feasibility study and discussions between LOTS Group and City of Stockholm, some modifications were made which is further explained in this report and listed in table “Redefined and decided KPIs to evaluate”:

	Table 5. Redefined and decided KPIs to evaluate				
Category	Transport System		Environment		Social
Indicator name	Transport efficiency	Punctuality	PM10 and NOx emissions	CO_2 emissions	Driver attitude
Aspect	Total travel	Service reliability	Harmful particles	Emissions	Social aspects
Definition	Potential time saved by driving night hours	On time deliveries according to pre-planned route	Difference in particle emissions	Difference in CO_2 emissions	A reflection of working during off-peak delivery shifts

3 Methodology

3.1 Measuring the KPIs

The measurement of the KPIs are done through LTM. The software collects signals from all trucks connected to the system with a frequency of four (4) times per minute. This signal contains information about the positioning of the vehicle as well as CO_2 emissions, particle emissions and fuel consumption. This information serves as the input to the data analysis.

3.1.1 Sections of total transport route

Table “Sections of the total transport route” lists the distances and which restaurants are included in each of the sub-sections A, B and C of the total route. One reason for splitting the total transport route into sections is that each section starts and ends at the warehouse. This is important because it creates three complete cycle times that can be measured against each other and be used to see where the PHEV and references vehicles spend the most time:

Table 6. Sections of the total transport route

Section	Starting point	First delivery point	Second delivery point	Ending point	Distance (km)
A	Tuna gårdsväg 4	Götgatan 91	Hornsgatan 88	HAVI Warehouse	44.9
B	Tuna gårdsväg 4	Katarinavägen 1-3	Folkungagatan 50	Tuna gårdsväg 4	52.5
C	Tuna gårdsväg 4	Sveavägen 71	Liljeholmstorget 94	Tuna gårdsväg 4	54.1
Total transport route					151.5

3.1.2 Geofence zones

Every time a vehicle enters a geofence zone, a visit ID is created. All KPIs desired to measure are sorted and connected to that unique visit ID. Figure 1. LTM geofence zone design is a snapshot from the software, with the geofencing zones created across the relevant areas to measure. The red geofencing zones are transport routes that have been created according to the transport schedules. The unloading zones by the restaurants and the warehouse are marked in green and created according to unloading and loading addresses in the delivery schedule.

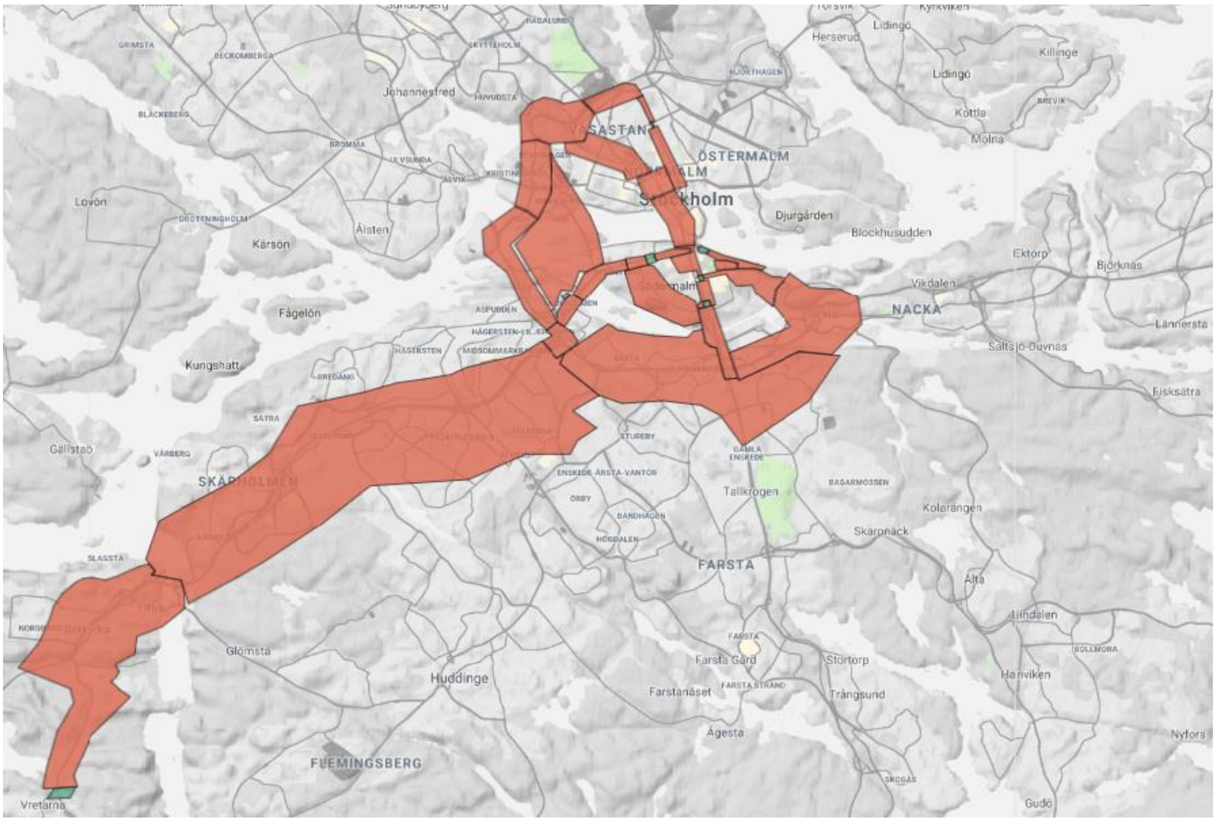

Figure 1. *LTM geofence zone design.*

3.1.3 Creating reference compatible geofence zones

The baseline for creating the geofence zones was done by drawing a single zone where the PHEV was allowed to operate according to the exceptions made by the Transport Department. Once this was completed, the reference vehicles routes needed to be studied. The reference trucks had other transport assignments, thus creating different routes, but together and combined they used the same sections as the PHEV. The outcome of the examination led to the creation of 29 zones. The geofence zones are thus used to both measure the PHEV and the reference vehicles. For pedagogical display, Figure 2. Geofence zone design rationale will demonstrate how the borders of the zones are determined by comparing reference routes with the test route:

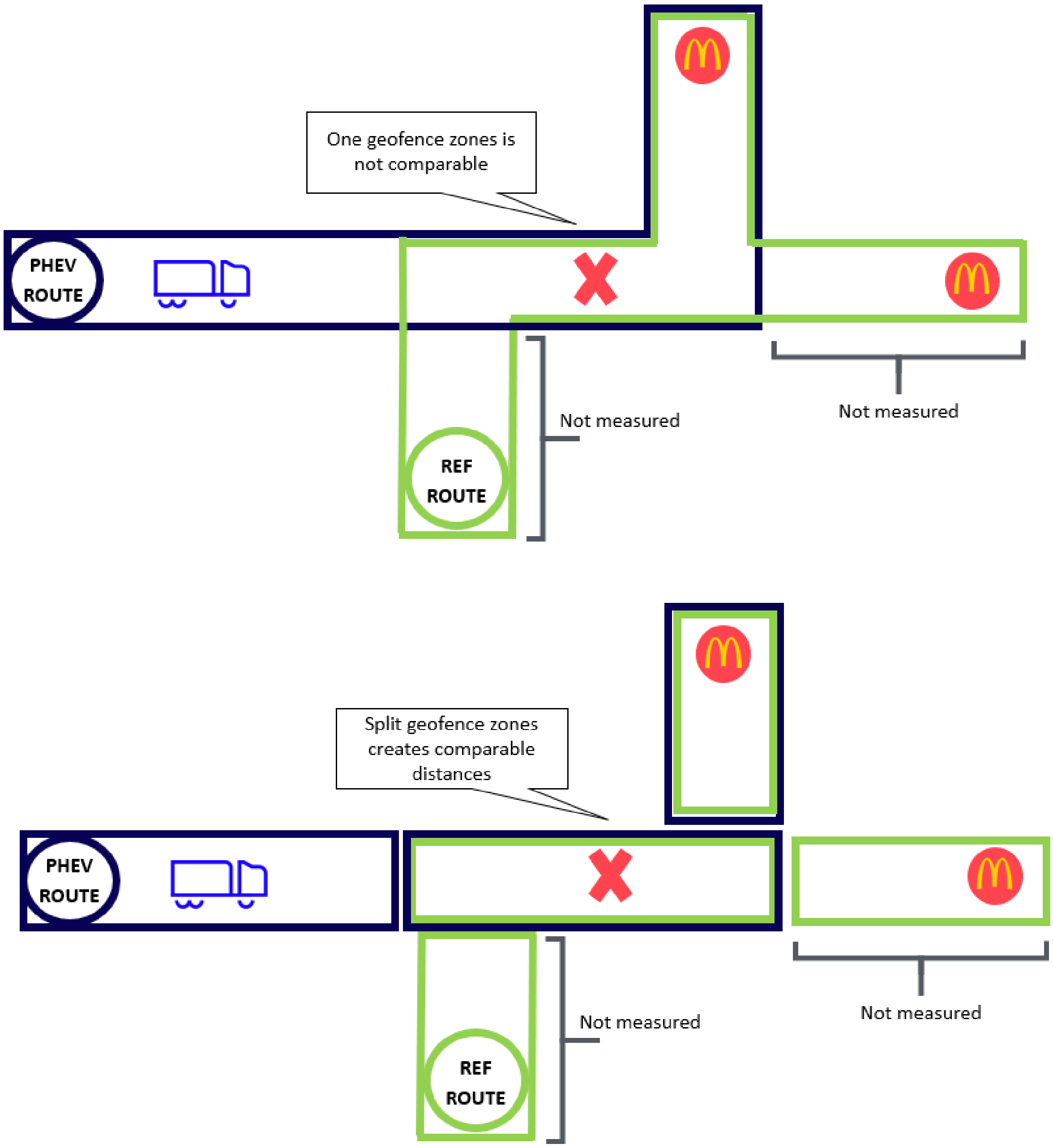

Figure 2. *Geofence zone design rationale.*

3.2 Validating the observations

Once the data is collected in LTM, excerpts was made continuously throughout the test period and pasted into models where the data was validated. This was done by looking at the observations in histograms and exclude those that were not applicable. The techniques to identify observations that were not applicable are different in their approach and used collectively, described in table 7:

Table 7. Data validation methods	
Using normal distribution charts	**Implied speed**
Excluding all observations that fell outside of the 75th percentile. Exemptions were made when vehicle was controlled in LTM playback and other explanations like queuing could be found	Cross-referencing time spent in zone with the size and location of the zone. All abnormally low or high speeds were discarded as well as speeds above the allowed inner-city zone for PHEV as it was capped (40 km/h)

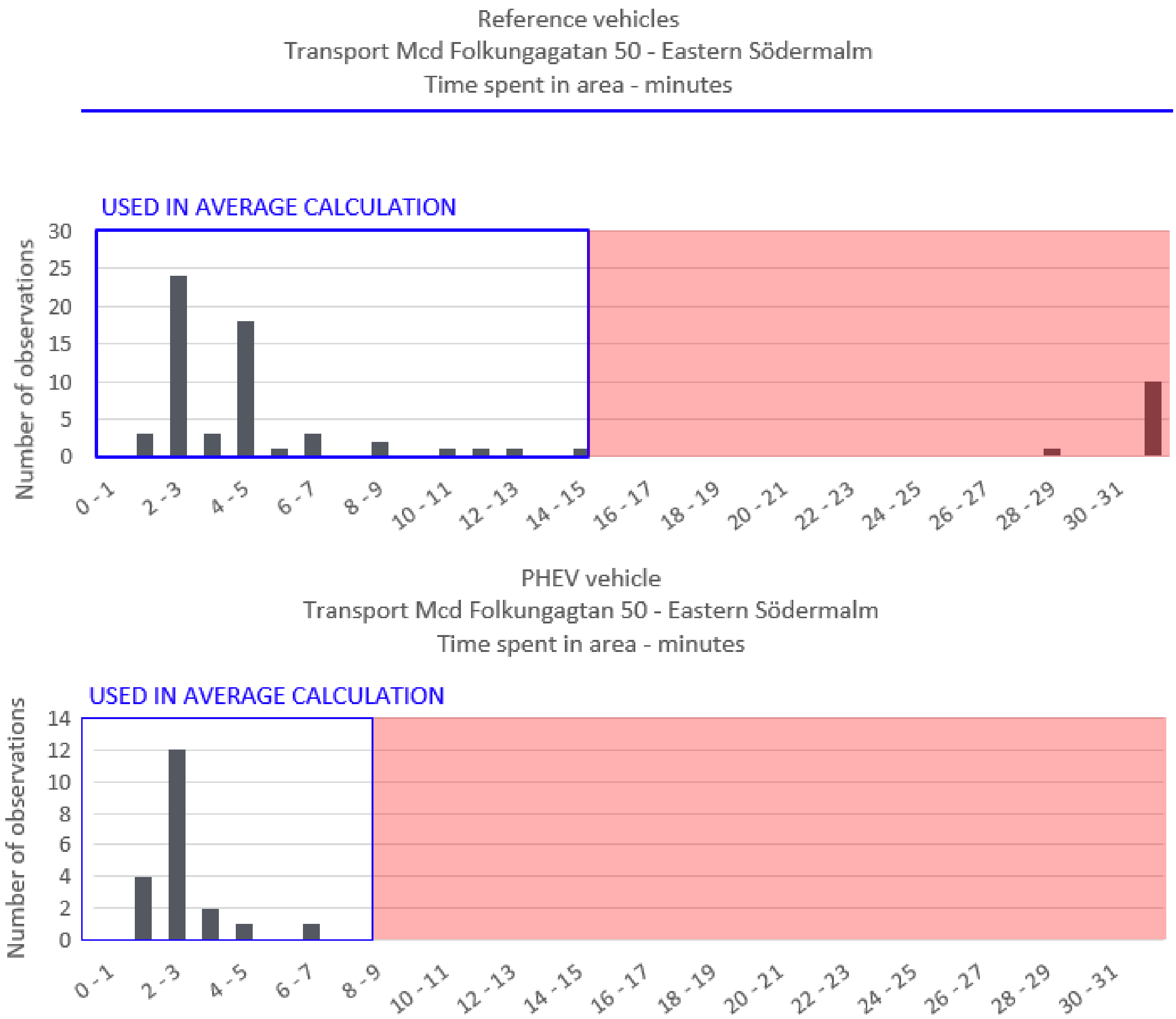

Figure 3. *Histograms.*

3.3 Emissions

The PHEV used its electric engine when entering the inner-city environment. The limits of the zone are drawn at several entry points to the inner city. The registered fuel consumption was thus only measured in the geofence zones located outside of the inner-city.

3.3.1 Fuel types and consumption

The reference vehicles differed in specification, further specified in table "Reference vehicles". The impact for the evaluation is that factors like fuel efficiency and which reference vehicles were used the most will affect the reference average values when comparing the PHEV and the reference vehicles.

3.4 Punctuality

To measure the punctuality of the deliveries, the delivery schedules have been collected for both the PHEV and the reference vehicle. The entry times into the unloading zones was then compared to the expected arrival. The unloading was measured when McDonald's accepted the deliveries and HAVI scanned this via the driver. All entries occurring earlier than expected time are considered to be on time. The reason for this approach is that qualitative interviews with the PHEV driver revealed that he often finished earlier than expected with his deliveries, and therefore drove to the next unloading zone prior to schedule. As this is a predetermined system that HAVI didn't change during the test period, it is not a performance indicator. Henceforth, only deliveries occurring later than expected were measured as a difference to expected delivery time. The arrival times are grouped into time interval of five (5) minutes and compared between the PHEV and the reference vehicles. The expected window of delivery is an agreement between McDonald's and HAVI of +/- 30 minutes to the delivery schedule.

4 Analysis

4.1 Key observations

The first recorded transport assignment was made Sunday night at 2019-01-13. During the test period, a total number of 96 PHEV total transport routes occurring on Sundays, Mondays and Thursdays have been measured. Table "PHEV and Ref vehicles sample size" is used to translate the amount of data used for the reference vehicles routes to a comparable data metric used to measure the PHEV routes. Every unique visit ID that has been validated as pertinent is used to create an average time spent in each zone. Adding up the average time spent in the zones for the total transport route and sections A, B and C creates the total time to carry out the transport assignment.

Table 8. PHEV and Ref vehicles sample size

Vehicle	Visit ID	Start date	End date
PHEV	8 921	2019-01-13	2019-08-21
Reference vehicles	17 453	2018-10-25	2019-08-21

4.2 Transport efficiency

Following figures show the time difference between the PHEV and the reference vehicle in carrying out the transport assignment expressed as cycle time minutes. The comparison is both displayed on a total transport route level, and split to the sections A, B and C:

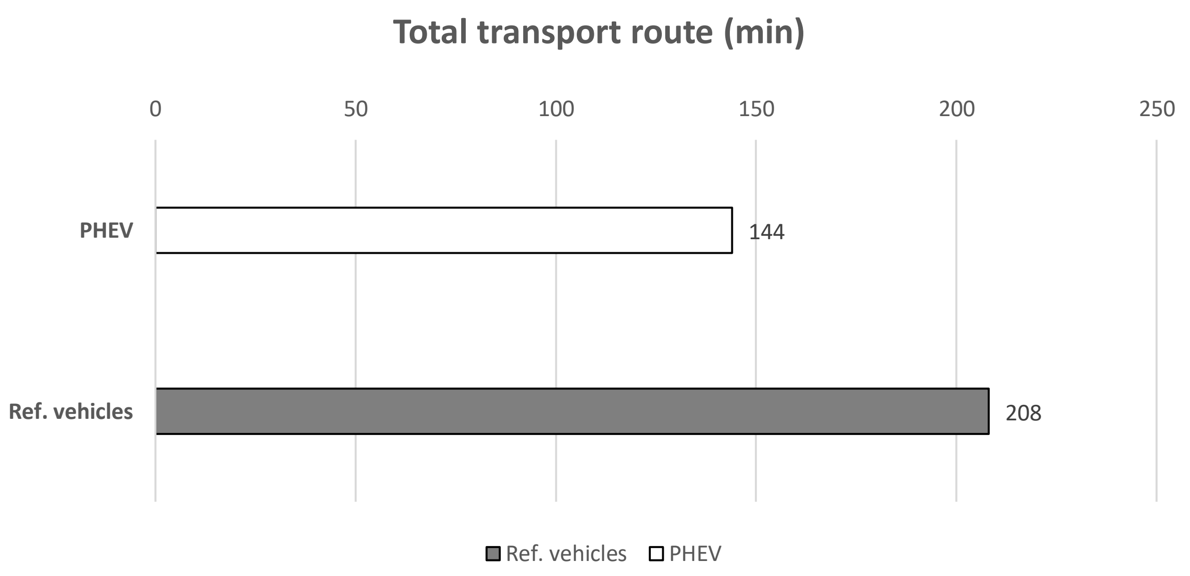

Figure 4. *Total transport route.*

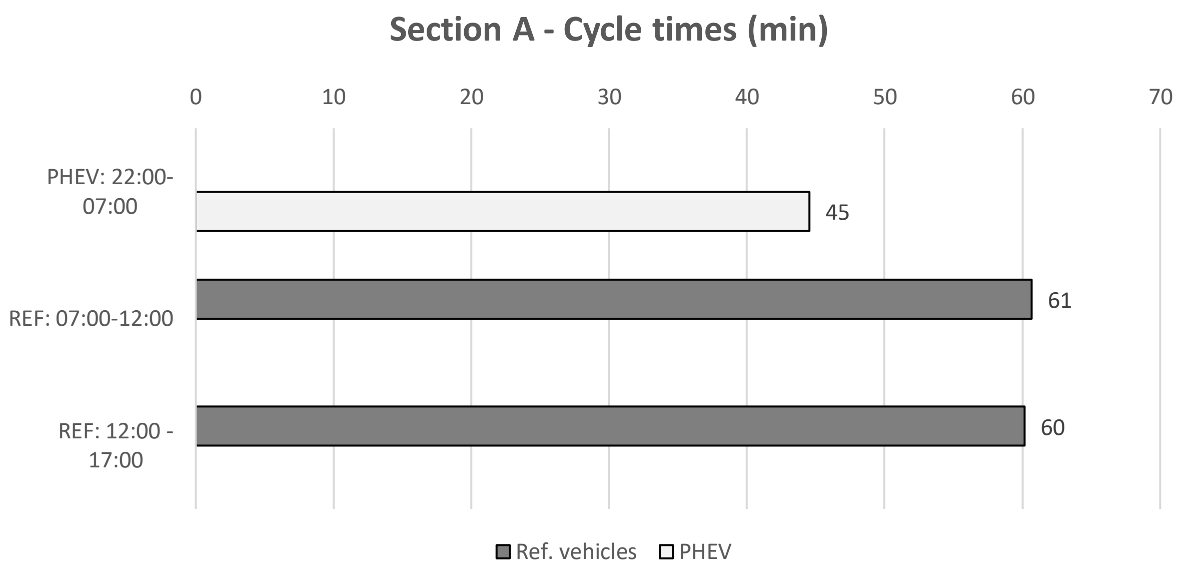

Figure 5. *Section A – Cycle times.*

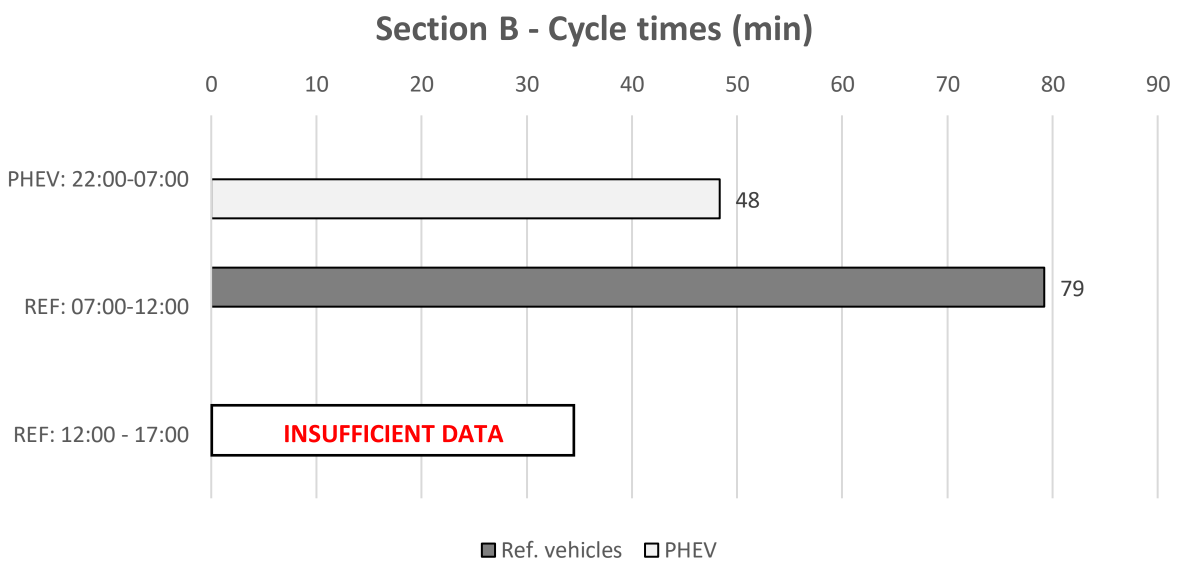

Figure 6. *Section B – Cycle times.*

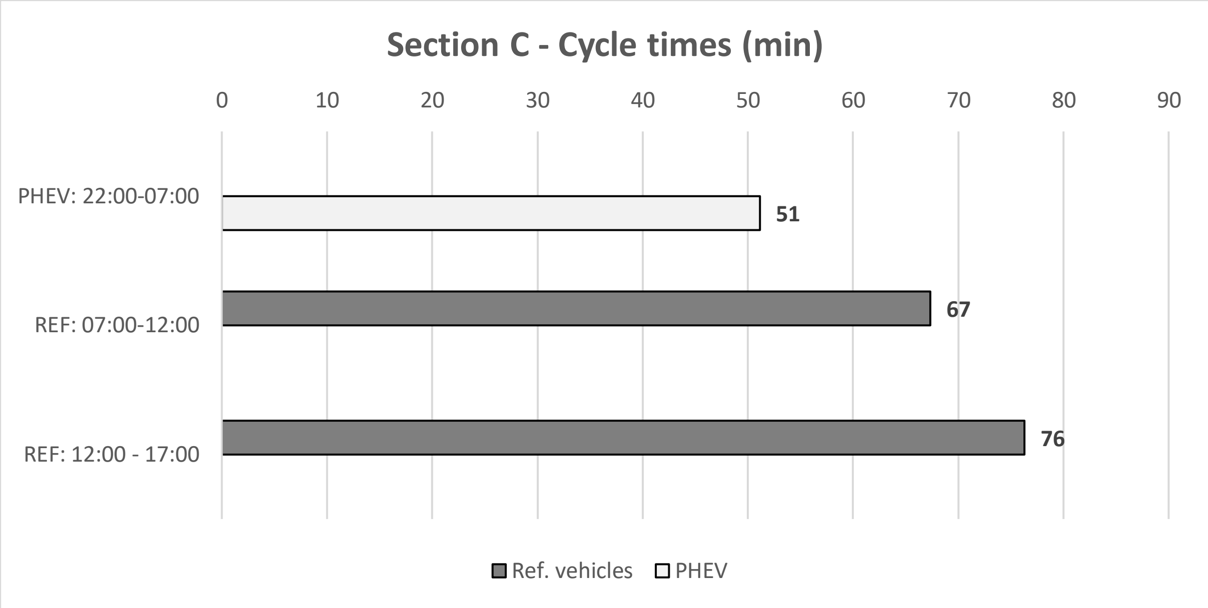

Figure 7. *Section C – Cycle times.*

Table "Breakdown of time differences" shows the aggregated and split time difference compiled:

Table 9. Breakdown of time differences			
Metric	**Ref vehicles (min)**	**PHEV Nighttime (min)**	**PHEV difference to Ref vehicles (%)**
Total transport route	205.7	144.1	-30%
Section A 07-12	59	44.6	-24.7%
Section A 12-17	62	44.6	-25.9%
Section B 07-12	79	48.3	-38.1%
Section B 12-17	N/A	48.3	N/A
Section C 07-12	66.0	51.1	-22.6%
Section C 12-17	76.1	51.1	-32.8%

For all tested time intervals, sufficient data existed to make a comparison for six (6) out of seven (7) desired parameters. For section B time interval 12-17, there was a data gap with zero observations in two geofence zones that would be needed to create a full comparison.

4.3 Punctuality

Table 10. Delivery precision			
Metric	**PHEV**	**Ref vehicles**	**PHEV difference to Ref vehicles**
Number of deliveries	475	816	-341
On-time deliveries	453	747	N/A
Delivery precision	95.37%	91.54%	3.83%

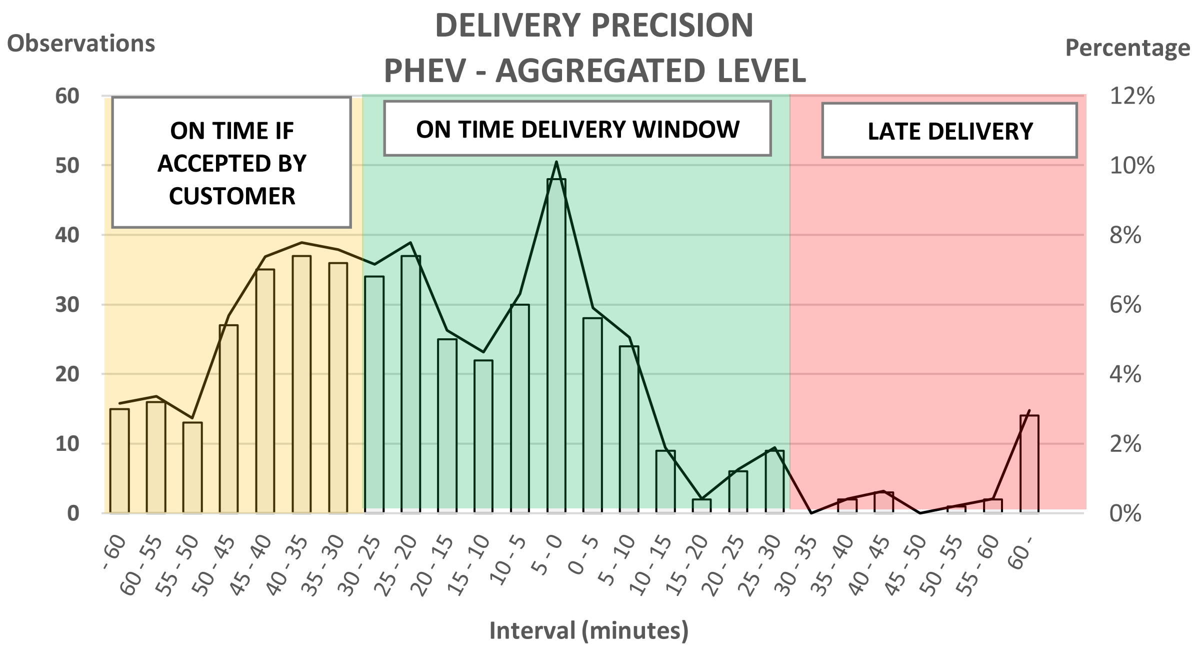

Figure 8. *Delivery precision PHEV*

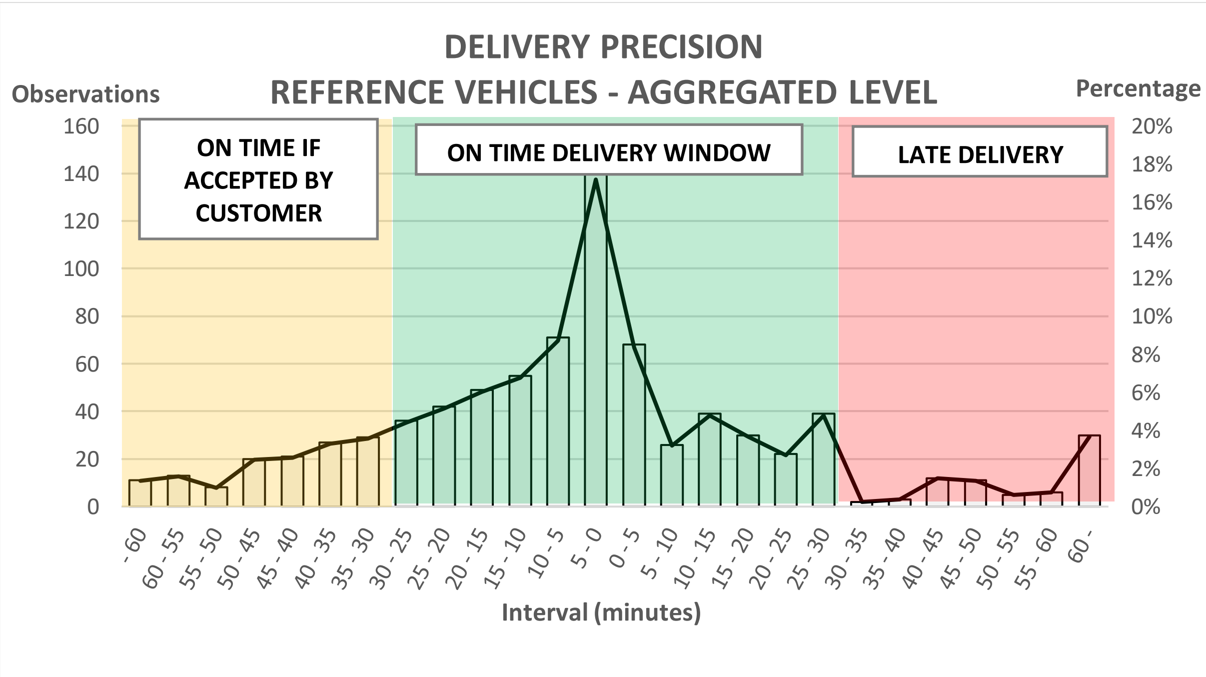

Figure 9. *Delivery precision Reference vehicles*

4.4 CO_2 Emissions

The fact that the PHEV runs on electricity for a large part of the transport route creates a natural difference in emission levels when compared to the reference vehicles that is not connected to the time of day vehicles are driving. Therefore, a total difference in CO_2 emission for the total transport route is complemented with a comparison to the transport zones where the PHEV runs on HVO. This is outlined in table "Breakdown of CO_2 emissions":

Table 11. Breakdown of CO_2 emissions			
Metric	**Ref vehicles (kg)**	**PHEV Nighttime (kg)**	**PHEV difference to Ref vehicles**
Total transport route	188.5	105.7	-43.9%
Part of total transport route using combustion engine	132.5	105.7	-20.4%
Inner city	56.0	0	-82 kg

4.5 PM10 and NO_X Emissions

The same logic as with CO_2 applies to emissions of PM10 and NO_X as the combustion engine is used only on parts of the transport route:

Table 12. Breakdown of emission differences – PM10			
Metric	**PHEV average (grams)**	**Ref vehicles average (grams)**	**PHEV difference to Ref vehicles (%)**
Total transport route	0.93	1.3	-28.1%
Part of total transport route using combustion engine	0.78	1.02	-23.7%

Table 13. Breakdown of emission differences – NO_X			
Metric	**PHEV average (grams)**	**Ref vehicles average (grams)**	**PHEV difference to Ref vehicles (%)**
Total transport route	10.18	67.33	-80.3%
Part of total transport route using combustion engine	10.18	51.60	-32.9%

4.6 Driver attitude

An interview with the driver was conducted on May 17th. The questions asked was designed to capture how working at night affected the driver's well-being and performance. As only one driver was used for the nightly transports, the outcome of the KPI is limited to one personal experience. There is no general applicability to determine whether other drivers would enjoy working at night. However, several important observations were made that helped the project and gave insight to the conditions of driving at night. The driver was overall very content with his work situation. The following table is a summary of the interview with quotes:

Table 14. Driver interview summary

#	Question	Category	Quote
1	How long have you been working as a truck driver?	Background	"I have been driving for two years. I took my driver's license in Sweden and passed both the theory and practical test on the first try"
2	Do you feel tired when working at night?	Well-being	"Not at all – For me, it's easy. You don't get irritated or upset over other traffic like in daytime driving which makes you less tired"
3a	How is your sleeping pattern affected?	Well-being	"It was worse when I drove for two consecutive nights and then worked two daytime shifts the following days. Now, I work three nightshifts with rest in between which is much better. I don't go to sleep directly after work, it takes a while to get sleepy. Usually, I wake up at 3-4 pm. Then I have some food, do whatever and later get back to work."
3b	And when do you start and finish the shift?	Well-being	"My shift starts at 9 p.m. I get in the truck and start driving at 10 p.m. I am finished by 7 a.m."
4	Does your working schedule effect your social life negatively?	Social effects	"After I have slept, I spend time in the neighborhood before getting in my car and driving to work. It's not bad – Since I only work three days a week, I have plenty of time for social life"
5a	What is your perception of the amount of traffic and how does that effect your driving?	Congestion	"When I start the shift, there is very little traffic. Especially around here in Botkyrka [Outside inner-city environment]. In Södermalm [Inner-city environment] and the city there's always people you know, but still much less traffic than daytime"
5b	Does this make it easier to drive?	Congestion	"Yes – Due to less traffic, it's much easier to maneuver and fewer other vehicles to consider."
6	Does driving at night make it easier to park?	Parking	It's a big difference as there is more space not used by other vehicles. Especially since they are rebuilding in connection to some of the restaurants like Hornsgatan 88 and Götgatan 91"
7	Is there a difference to daytime when you arrive at the restaurants?	Unloading	"For all the six restaurants, it's the first time they receive deliveries at night. They seem to be happy about it, because there are less customers which give them time to do the unloading in a less stressful manner – And have time to prepare the breakfast"
8	What is your perception of noise in connection to unloading?	Noise	"Because the vehicle has completely switched to electric in all unloading zones, I feel there is nothing disturbing about make the unloading at night"
9a	Would you consider continuing driving at night?	Working conditions	"Yes – More than happy to do it."

9b	Are there any economic benefits to driving at night?	Working conditions	"Not a major difference – We do get paid additionally for nightwork, other than that its according to the collective agreement"
10	Are there any common deviations from the transport schedule?	Route specific	"I am usually early to Götgatan 91 – Because there are people there ready to handle the unloading, I can finish earlier and head straight to Hornsgatan 88 prior to schedule"
	Do you believe driving at night is faster than daytime?	Route specific	"Yes of course – It's not comparable. One major reason is the traffic lights sensors – Because it's almost only me and buses driving, I drive mostly without stops"
11a	Do you always charge the truck by the electric charging point at Slussen?	Electric	"Sometimes there is no need to charge the vehicle – Because it's downhill part of the route, no electricity is used although the vehicle has switched from combustion engine to electricity"
11b	Does the vehicle switch automatically to electric when passing the various entry points to inner city?	Electric	"Yes – I can't use the combustion engine here and here [Pointing at bridges and roads to inner city]"
12	Is it tougher to get help if something goes wrong during work at night?	Support	"It has only happened once, and the guys from Scania has showed me how to handle basic errors like a warning signal"

5 Conclusions

5.1 Comparative performance PHEV and Ref vehicles

Key finding from the analysis shows that the PHEV is outperforming the reference vehicles in all KPIs measured as the goal is to achieve higher transport efficiency in time and reduce emissions. The explaining variables behind the results are partly connected to the technology of the PHEV and the fuel efficiency differences between the PHEV engine and the reference vehicles. The decreased congestion in the city at night is most likely affecting both accuracy of deliveries and faster pace, but the amount of traffic on roads is not quantified.

5.1.1 Time savings conclusions

When comparing the different sections, the highest time savings were made in section B at the time interval 07-12. The spatial characteristics of that section contains least amount of inner city when compared to the other sections. This allows for higher speeds to be reached than in the inner-city when compared which gives bigger differences when congestion arise. That is partly explaining why such a drastic time difference has been measured. The time interval is also including the rush hours for commuters entering Stockholm from the south. This is likely resulting in higher usage of the roads during daytime hours. The pattern is the same for the other sections. Section A is the part of the total transport routes which utilizes the express way the least. This is also where the smallest time difference was measured. One additional point to make out is that there are designated loading bays for the delivery points. For a general comparison with individual passenger cars or transporters without designated parking space, there is likely a big additional reduction in cycle times. This is due to the daytime traffic using up more of the parking space and more time would be used in search of an empty slot.

5.1.2 Punctuality

Since the PHEV carried out all necessary deliveries to the restaurants, there was no need for additional daytime resupplies. In order to solve that issue and make a comparison with substantial reference material, observations for the whole year of 2018 and beginning of 2019 up until the start of the test was measured. The data came from HAVI's own recording of delivering the goods, which is conducted through scanning the delivery upon arrival. There is a distinction to be made between delivery according to plan and commercially agreed punctuality, which is displayed in the figures. The delivery window for HAVI to arrive and unload the products is set to +/- 30 minutes to plan. Should they arrive earlier than that and the customers choose to accept the delivery, this is treated as an on-time delivery. The yellow-toned part of the figures is thus partly containing deliveries done prior to the 30 minutes but counted as on-time. The comparison shows an increase in delivery precision with 3.83%. There is also a visible difference in the distribution of the charts. Proportionally more early arrivals were measured for the PHEV – A reflection of the fact that less disturbances and faster speeds between stops pushed the schedule to be lagging behind the PHEV.

5.1.3 Emissions conclusions

The CO_2 emission reductions are significant, even when only comparing the sections of the total transport route where both the PHEV and the reference vehicles used the combustion engine. The basis for all emissions calculations comes from the amount of fuel used when driving which is then applied to a model that takes several parameters into account. The fact that the reference vehicles fleet is mixed between Euro V and Euro VI engines as well as having different horsepower effects will create an average performance based on all the various specifications. Therefore, a newer or older fleet with higher or lower Euro class engines will create a different result. It is however a reasonable representation of the most common heavy-duty vehicles operating in Sweden. More than 20% in CO_2 reductions can be explained partly when looking at the geofence zones. The ones where combustion engine is used show significant differences in average time spent in area. This is once again a reflection of less queuing, higher speeds possible due to less traffic on the road and more traffic lights sensors turning green. The big reduction in NOx emissions was naturally explained as only the combustion engine produces these particles. For PM10 which is created partly by raveling the asphalt when driving, the difference is therefore lower.

5.2 Comparison to earlier projects

As part of the evaluation, LOTS Group was asked to compare its own evaluation to prior work done in the past that could be connected to off-peak deliveries. "Off-peak City Logistics – A case study in Stockholm" (Pernestål et al.) reported about a similar transport efficiency evaluation that took place in 2017. This study was a combination of both a Volvo electric truck and a Scania biogas truck. The KPIs were similar in regard to transport efficiency, but the methodology was partly different. Instead of creating a reference route with help of geofence zones, an actual reference route was driven and recorded with GPS positioning and noise equipment. While this is a strong method for creating a comparison, the sample size was smaller than the one used for this evaluation.

5.2.1 Scope of earlier projects

The route was driven 5 times during the course of 13 days (9^{th} May – 22^{d} of May 2016) which could be compared to the 96 total transport reference routes comprised by 17 453 Visit IDs. For commercial and practical reasons, it appears to be hard to use an exact reference daytime route for longer time periods. One solution to this may be to combine the two methods. The actual trial would work as an additional validation of the geofence zones measurements and give a higher certainty in the evaluation.

The average speed recorded from "Truck A" in the earlier trial during off-peak deliveries ranged from 59-64.7 km/h. This can be compared to the PHEV who measured the following average speeds:

Table 15. Speed comparisons

Section	km	Implied speed PHEV (Km/h)	Implied speed Ref (Km/h)
Distance Section A	44.9	60.48	46.45
Distance Section B	52.5	65.19	57.27
Distance Section C	54.1	63.48	42.55

The values from the PHEV are similar to those of the "Truck A". This serves as a validation of the measurement method which were done in different manners but ended up with similar results.

5.3 Limitations of evaluation

The best possible testing environment is achieved when the test vehicle and the reference vehicles are using the exact same route, preferably during the same time period. In this evaluation, reference data is created by combining and adding geofence zones. The accuracy of the data is thus affected, since the characteristics of the zones will sometimes create faulty data gathering. This is not fully offset by the data validation as a vehicle can fall within the same time range as the intended measured one, without driving the exact same route.

5.4 Future initiatives and general applicability of results

This evaluation is best used as an indicator of the positive potential in utilizing off-peak deliveries in urban areas. The data is measured on a specific route in Stockholm which necessarily do not translate to the same percentual improvement in other cities. It is however a robust decision basis material for any actors looking to perform similar studies. The potential societal and economic gains of balancing the pressure on urban infrastructure over the day are clear. With ever improving technology and progressive legislative authorities willing to try new ways going forward, the future of urban transport is in a state of change.

6 Annex

6.1 Delivery schedule

Table 16. Delivery schedule			
Section	**Description**	**Time**	**Activity**
A	Work shift starts	20:45	Loading
A	Vehicle starts driving	21:30	Driving
A	Arrival McDonald's Götgatan	22:00	Unloading
A	Vehicle starts driving	22:30	Driving
A	Arrival McDonald's Hornstull	22:45	Unloading
A	Vehicle starts driving	23:15	Driving
A	Return to Warehouse	23:45	Charging
B	Resupply of goods	23:45	Loading
B	Vehicle starts driving	00:30	Driving
B	Arrival McDonald's Slussen	01:00	Unloading (charging 30 min)
B	Vehicle starts driving	01:30	Driving
B	Arrival McDonald's Folkungagatan	01:45	Unloading
B	Vehicle starts driving	02:15	Driving
B	Return to Warehouse	02:45	Charging
	Driver break	02:45	Break
C	Resupply of goods	03:45	Loading
C	Vehicle starts driving	04:30	Driving
C	Arrival McDonald's Sveavägen	05:00	Unloading
C	Vehicle starts driving	05:30	Driving
C	Arrival McDonald's Liljeholmen	05:45	Unloading
C	Vehicle starts driving	06:15	Driving
C	Return to Warehouse	06:45	Parking
C	End of work shift	07:00	End

6.2 Route sections

Following figures are snapshots from LTM with sections of the total transport routes from the PHEV. The McDonald's restaurants are added for pedagogical display:

Figure 10. *Section A.*

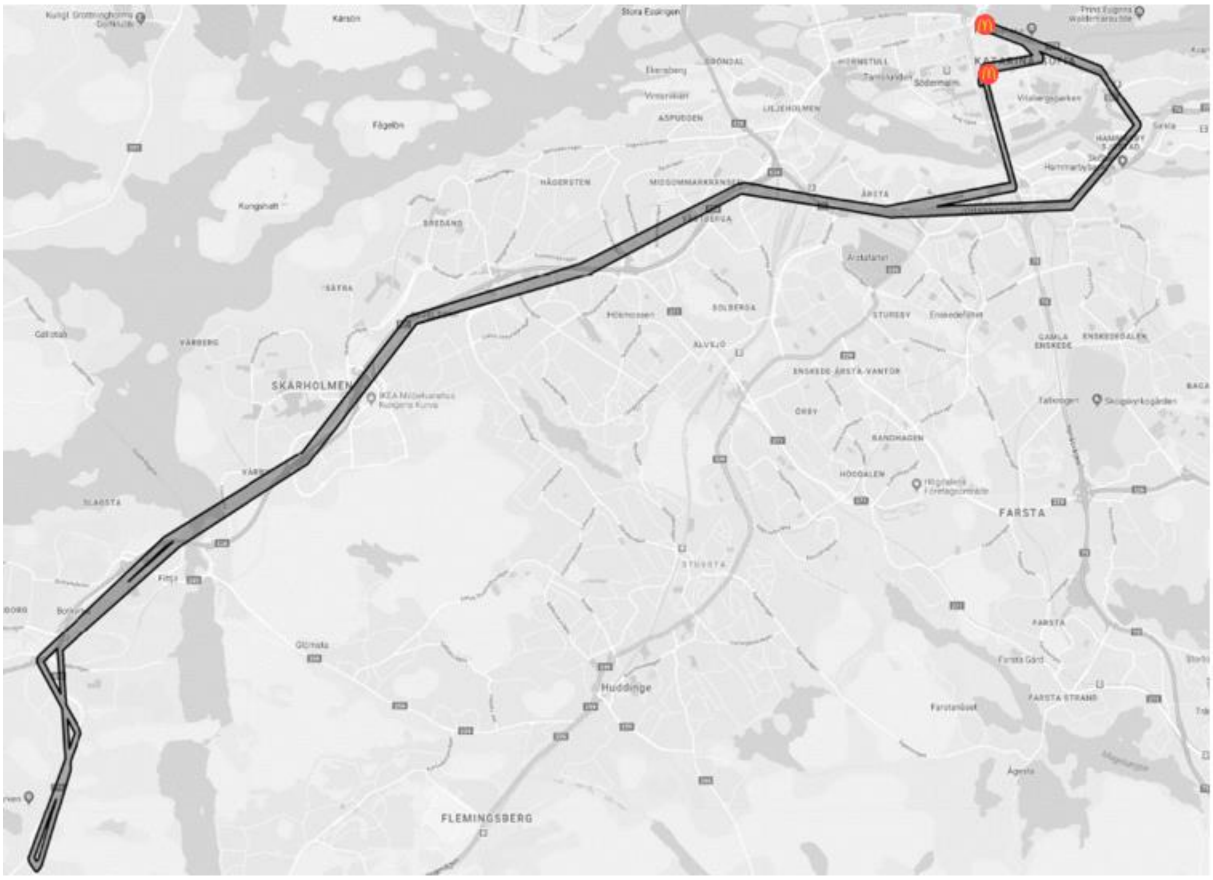

Figure 11. *Section B.*

Figure 12. *Section C.*

Figure 13. *LTM Snapshot with geofence zones explained.*

6.3 Geofence zones observations

Table 17 – Geofence zones statistics: PHEV

Zone number	Visit ID	STD DEV	Max value (min)	Min value (min)
1	15	9,13	26	0
2	88	1,34	19	1
3	24	0,83	2	0
4	32	1,98	8	0
5	373	1,67	17	1
6	583	2,75	25	3
7	204	1,60	6	0
8	353	1,50	11	0
9	226	0,89	6	0
10	163	0,70	5	1
11	93	0,76	6	2
12	228	0,99	8	0
13	78	2,63	16	1
14	250	1,39	6	0
15	211	0,96	6	0
16	163	1,17	4	0
17	299	1,48	16	0
18	183	1,18	8	1
19	243	1,06	4	0
20	613	2,26	9	0
21	604	4,93	41	3
22	239	1,15	10	1
23	196	0,89	5	0
24	342	14,41	64	0
25	145	12,19	42	0
26	121	24,67	98	0
27	255	11,78	59	0
28	127	12,40	58	0
29	184	15,28	72	0
30	22	19,17	82	0

Table 18 - Geofence zones statistics: Ref vehicles				
Zone number	Visit ID	STD DEV	Max value (min)	Min value (min)
1	14	3,01	26	0
2	29	1,40	19	1
3	802	3,16	2	0
4	794	7,12	8	0
5	1790	5,34	17	1
6	3587	11,14	25	3
7	186	3,60	6	0
8	907	1,23	11	0
9	532	1,39	6	0
10	49	9,96	5	1
11	67	2,92	6	2
12	244	0,56	8	0
13	372	13,81	16	1
14	1187	1,09	6	0
15	959	0,60	6	0
16	173	1,02	4	0
17	68	9,88	16	0
18	44	5,31	8	1
19	101	0,96	4	0
20	1180	1,42	9	0
21	3923	6,67	41	3
22	35	1,71	10	1
23	32	0,63	5	0
24	55	19,98	64	0
25	28	9,80	42	0
26	11	5,67	98	0
27	60	8,81	59	0
28	39	16,80	58	0
29	29	12,01	72	0
30	94	1,32	82	0

6.4 Project partners

LOTS Group
Daniel Bonna – Project Manager
Daniel.bonna@lotsgroup.com

LOTS Group
Fredrik Hjelm – Lead Developer Digitalization
Fredrik.hjelm@lotsgroup.com

HAVI Logistics
Camilla Eklöf – Quality, Safety & Environmental Manger

City of Stockholm
Robin Billsjö – Urban Freight Strategist

THE CIVITAS INITIATIVE IS CO-FINANCED BY THE EUROPEAN UNION