

Deployment of an all-electric connected taxi fleet

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Summary

This case study presents the early lessons learned from an entrepreneurial project of launching and operating a purely-electric taxi fleet in an urban environment subject to harsh winter conditions. Challenges go from the planning of private charging infrastructures, to implementing car-swapping strategies that are calculated by an IT-based fleet dispatch system that monitors the fully-connected fleet in real-time. Operating a company-owned fleet with employee drivers that never drove an EV before, this project proves to be an interesting challenge on human level too. The wide range of daily events, such as rapid weather fluctuations or human errors, are all constraints that make using EVs as taxis, an interesting experience.

Keywords: passenger car – fleet – deployment – case-study – Canada

1 Introduction

The objective of this entrepreneurial project is to establish the optimal practices and mode of usage of a purely-electric taxi fleet in an urban environment subject to both harsh winter and hot summer conditions. Given the current mutations within the taxi industry, with the introduction of new players like Uber, the market demonstrates the need for a different approach to this type of urban transportation. This provides the ideal opportunity to leverage the environmental benefits and comfort of EVs, within the framework of a regulated and professional service, providing convenience and peace of mind to users.

Operating such a fleet of electric passenger cars in a commercial 24/7 duty was soon combined with objectives such as trying to maximize the number of km driven per minute of recharge. In addition to maximizing day-to-day operation, between trips with customers, recharge events and maintenance stopovers, this fleet performance pursuit brought the question of battery life subject to frequent quick-charging events and how to evaluate its degradation.

While the current project is still at an early stage, the present case study represents an interesting snapshot of the work accomplished so far. Depicting the different aspects of this endeavor and gathering lessons learned, on all angles, operational, technical and in lab testing, this is also the first step of many others, which will lead our team to the goal of defining the “ideal” EV to use in taxi fleet application.

2 Context of this project

2.1 Political momentum

This project is also part of a larger effervescent pool of change in the province of Québec. In fall 2015, provincial government launched an initiative called *Transportation Electrification Action Plan* [1] that aims at creating a positive context with grants and investments into EV industry and its related technologies. Strong with an electricity production portfolio that is one of the cleanest on the planet, only 2nd to Norway

[2], Québec is also the host of advanced industries and research organizations that will leverage its electrification mission to great levels.

2.2 Presentation of IVI

One of these key players of this provincial plan is the Innovative Vehicle Institute (IVI). The mission of IVI is to support businesses and organizations in the fields of applied research, development, assessment and implementation of innovative vehicle technologies. The goal of IVI services is to support its clients, mostly SMEs, in order to develop innovative and technologically advanced products. IVI's projects target transport electrification, vehicle energy efficiency and reduction of greenhouse gases (GHG) and polluting emissions.

IVI dedicated a team of four members to support Taxelco's EV taxi project: support engineer, test engineer, lab technician and overall project leader. The mandate they have, over an initial pilot-project period of 18 months, is threefold:

- Complete a study about the degradation of the HV batteries in a such a rigorous taxi-fleet-duty, over the initial 18-month period
- Train Taxelco's technical and non-technical team members and numerous taxi drivers to the bases and best practices of operating an EV fleet
- Act as a dedicated local engineering support for the implementation of the EV fleet and their additional onboard systems, facilitate deployment of charging infrastructure from different partners and help team to ramp up daily operation strategies

2.3 Presentation of Taxelco

The objective of Taxelco is to consolidate the interests of the taxi industry. With this approach, they want to ensure that the economic and social benefits derived from the use of fully electric vehicles, the creation of operational synergies and the efficient use of information technologies will remain in the hands of its constituents. This ambitious project will help position Montreal as a green, avant-garde city where public transports are a means to responsible economic and social development, echoing the unique, cultural and innovative personality of its citizens.

This collaborative and supervised pilot project started in November 2015 with 60 electric vehicles driving around Montreal. On a technical standpoint, for Taxelco, the objective of this project is to optimize the performance of electric vehicles operating as taxis and in Montreal's rigorous weather conditions. This will help to shape company's methods and models for its own fleet growth, but it will also help to build Taxelco's commercial offer to other cities who are looking into launching their own EV taxi fleets.

2.4 Overview of electric taxi initiatives in the world

Of course, the current project is far from being the only one involving EV in taxi application. Here is a non-exhaustive overview of a few notable electric taxi projects around the world along with their choice of EV:

Table1: Non-exhaustive list of notable EV taxi projects already in operation

Company	Location	Launch	Chevrolet Volt	Tesla S	Nissan LEAF	Nissan e-NV200	Kia Soul EV	BYD e6
EcoCab	Longview WA / Portland OR	2012 (Longview) / 2015 (Portland)	X	X	X			
TaxiElectric	Amsterdam, Holland	2011		X	X			
Connexion	Amsterdam, Holland	2014		X		X		
TCA	Amsterdam, Holland	2014		X	X	X		
Various operators	Bruxelles, Belgium	2014						X
Budapest Taxi	Budapest, Hungary	2014			X			
Various operators	Barcelona / Madrid, Spain	2014			X	X		
Abel	Amsterdam, Holland	2016					X	

2.5 Distinctive elements of Taxelco project

2.5.1 Climate

One unique element of this EV taxi project is the climate. Montreal city is subject to a very wide range of temperature. Weather is cycling yearly from humid July days over 30°C to bone-freezing January episodes of temperature below -25°C. Adding important winter snowfalls to the mix makes it a challenging place to be an EV driver. Those are considered harsh winter conditions even in Norway, great leader in EV usage, where climate is more temperate and snowfall less abundant [3].

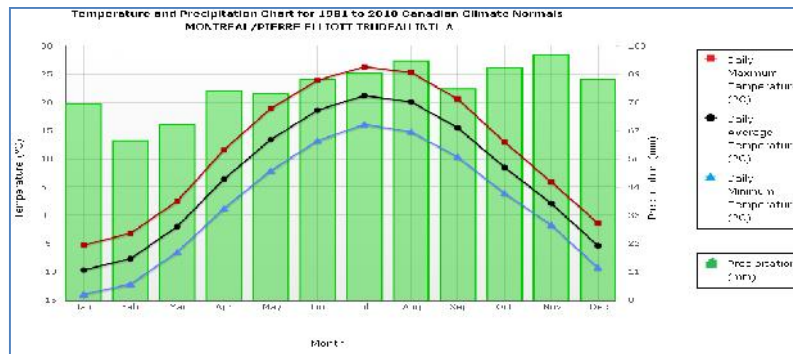


Figure 1: Montreal yearly weather cycle [4]

2.6 Taxi industry

There is a lot of taxis in Montréal, around 1 per 417 inhabitants compared to 1 per 600 in New York City. To operate a taxi car in Montréal, in addition to owning a vehicle meeting mechanical requirements (such as wheel base length, vehicle weight, number of doors, etc.), one individual has to detain a taxi owner permit. Quebec province is split in zones where the quantity of those permits is limited by a commission (CTQ). In Montreal, permit owners are operating around 4400 of those permits. Therefore, to legally offer taxi service in a given zone, one has to buy or lease one of the existing owner permit per taxi vehicle in operation. A portion of the permit owners are taxi drivers, the rest are of the permits are leased to a pool of drivers.

In this context, Taxelco's EV taxi project is aiming at operating within those permits, by gradually renting them from actual owners. Those owners are also welcome to join Taxelco's team of employee-drivers. Far from unbalancing Québec's existing taxi industry, this project's goal is to proudly turn it into a clean, attractive and distinctive asset for Montréal and the province.

3 EV taxi fleet

3.1 Current fleet

The initial EV fleet has 60 vehicles, allocated as following:

Table 2: Current fleet

Quantity	Manufacturer	Model	Style	Year	Battery size	Battery chemistry	EPA range	Motor(s)	Layout
24	Kia	Soul EV		2016	27kWh	NMC (LiNiMnCo)	149km	80kW	FWD
24	Nissan	LEAF		2016	30kWh	NMC (LiNiMnCo)	172km	80kW	FWD
2	Tesla	S 70D		2016	70kWh	NCA (LiNiCoAlO2)	386km	254kW	AWD
10	Tesla	S 90D		2015	90kWh	NCA (LiNiCoAlO2)	434km	311kW	AWD

3.2 EV models selection

The choice of vehicles was based on very simple criteria. Retained vehicles had to be:

100% electric: The goal was to have a 100% emission-free fleet. This also eliminates engine maintenance and ICE-related fluid handling. The company even use biodegradable products to do routine brake cleanups and vehicle washing. This criterion eliminated plug-in hybrids, such as: Chevrolet Volt, Toyota Prius PHV, Ford C-Max Energi, etc.

Equipped with quick-charge port. A taxi vehicle is only useful when it is in duty, not stopped at a charging station. This eliminates any EV that do not have either a CHAdeMO or DC-combo charging port, such as: Ford Focus EV or Mercedes B Class.

Suitable for taxi duty. The physical configuration of the car has to suit the usage of a taxi car. Vehicle has to offer some comfort for the rear passengers, allow sufficient space, head-wise and knee-wise, along with some luggage space for suitcases. On-boarding and off-boarding has to be easy and quick. This ruled out EV cars such as Mitsubishi i-MiEV, Chevrolet Spark EV and BMW i3, for obvious size and door configuration

Available here and now. With a pilot project starting in fall 2015, the team had to start a fleet with vehicles that were available and homologated for use in Canada. This excluded EV models from Renault or the Volkswagen e-Golf. Territories with zero-emission laws, such as California, have a greater choice of EV models, since manufacturer are sending their EV production to those places first.

3.3 Future expansion of the fleet

These criteria, along with the recent announcements of car manufacturers in various auto shows, also point out to some very interesting EVs that will soon be available to Canadian market. Taxelco is looking forward to add several Chevrolet Bolt and Nissan e-NV200 to its taxi fleet within the next year.



Figure 2: Chevrolet Bolt, Nissan e-NV200 and Metro-cab as pictured from manufacturers websites

In the way London did for its future generation of EV taxis with Metro-cab, it is also in Taxelco's future plans to enter into a venture where industrial partners would tailor-build the ultimate EV taxi according to the lessons learned from the actual pilot project.

4 Monitoring and dispatch of the fleet

4.1 Dispatch system

The EV fleet control system backbone interacts constantly with all vehicles through their onboard systems. Those systems include RFID access-control, GPS, driver interface tablet, datalogging hardware, etc. This backbone system also provides web-based real-time monitoring tools for the team of dispatchers in the control room. This system also relays dispatches information to drivers about their trips or upcoming charging events.

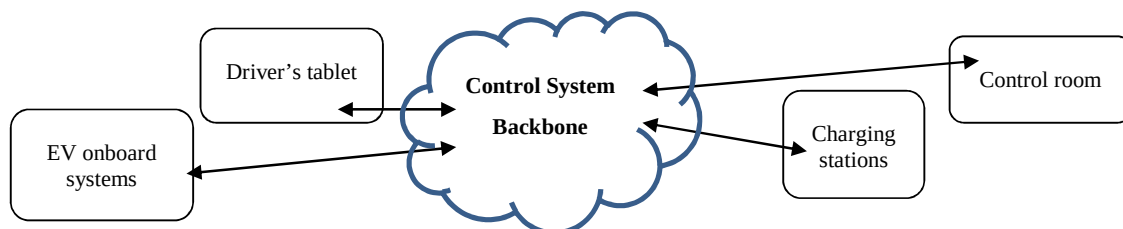


Figure 3: Taxelco's dispatch system architecture

4.2 Datalogging and monitoring

One axis of our monitoring work on the fleet is based around FleetCarma services. This Canadian company offers web-based services aimed at fleet managers. Their web-portal tool allows the user to generate reports based on cloud-stored data harvested in the fleet by datalogging devices installed in each vehicle.

FleetCarma engineers have gained access to the appropriate CAN-BUS messages found on the diagnostic port of most EVs. This system allows us to access car's SOC and charging status in relative real time. Refresh rate of such info to the cloud is once per minute and is accessed by Taxelco's backbone system, via an API, to run its taxi dispatch algorithm.

Other useful info is being logged by the FleetCarma equipment, such as instant energy consumption, type of recharge, vehicle speed, vehicle position, etc. All this info is logged into FleetCarma cloud and can be studied by fleet engineers and coordinators through a set of pre-configured reports.

5 Charging

5.1 Charging equipment

So far, the retained charging infrastructure has been deployed in partnership with two local suppliers who manufacture their own charging stations.

Table 3: Charging equipment

Quantity	Manufacturer	Model	Hardware	Type		Details	Access control
20	AddEnergie	CoRe+	AddEnergie	Level 2 - J1772		Wall mounted charging equipment	RFID / Remote proprietary
4	AddEnergie	SmartDC	AddEnergie	Level 3 - CHAdeMO		Stand up DC charging cabinet	RFID / Remote proprietary
2	Bectrol	Haltégo	Elmec	Level 3 - CHAdeMO		Complete self-contained charging station	Remote OCPP
2	Bectrol	Haltégo	Siemens	Level 3 - CHAdeMO		Complete self-contained charging station	RFID / Remote OCPP

5.2 Geographical distribution and installation

Level 2

Slower AC charging stations were only installed at Taxelco service center where taxi cars are stopping when not in use. This is the location where car washing, repair and maintenance events are centralized. As soon as a vehicle is parked at this location, it gets hooked to one of the 20 wall-mounted J1772 level 2 stations.

Level 3

While trying to determine the optimal private quick-charging station distribution over a city, one could be overwhelmed with the endless possibilities.

One could give priority to locations close to the central business district and downtown areas where the taxi trip density is higher. If the fleet is busy enough, such as rush hour, this would minimize the inevitable occasional taxi-downtime needed to commute to and from the charging station between customer trips. However, since the territory to cover is much larger than downtown area only, this empty commute trip would be very long for a taxi needing a recharge while it is still located far from downtown charging stations.

Another strategy could also be to distribute charging infrastructure equally on all the territory. This would spread the charging infrastructure to less dense areas but it might also lower the average empty trip length to the charging station if the downtown trip density fluctuates to lower levels outside rush hour. Those locations could also prove to become quicker and more practical in heavy traffic hours where the downtown locations could become difficult to access.

Other considerations affecting the positioning of charging stations is the possibility to use underground locations. With harsh winters, it is a non-negligible advantage to be able to charge in a snow-free environment where temperature is over 0°C. On cold winter days, even just a 20-30 minutes quick-charge event becomes a useful opportunity to defrost or wash an EV and lower the burden on the onboard battery-hungry HVAC system.

When choosing a location outside any building, another challenge is sourcing the electrical supply and managing the installation of the level 3 station and its related hardware (concrete slab, power transformer, underground cabling, etc.). The self-contained Bectrol stations we selected for outdoor locations are portable shelter-shaped structures that contain their own power transformer and electrical meter. They just need to be delivered to a site and hooked to the nearest electrical grid distribution infrastructure.

The strategy retained for the initial distribution of quick-charging infrastructure across the service area represents a compromise. Taxelco opted to put more AddEnergie charging stations in dense downtown area, taking advantage of underground and sheltered parking locations, but they also installed outdoor self-contained Bectrol stations in less dense locations across the taxi service area.

5.3 Charging strategies and planning

In taxi, like any other business, time is money. Furthermore, distance is also money, so when an EV taxi enters downtime to go to and from the nearest charging station, where it sits for 20 to 30 minutes, it is not contributing anymore. This is where Taxelco had innovated by deciding on a charging strategy that minimizes downtime.

Car-swapping

Being employees, Taxelco's drivers are not bound to a specific car. They can be dynamically authorized by the system to access any vehicle of the fleet at any time. This is why the company adopted a car-swap strategy for charging event. This way, the EV charging downtime is not linked anymore to the driver availability.

When a vehicle state of charge reaches the threshold for charging, the driver receives a message indicating the location of the selected station but, more importantly, the vehicle number of a taxi car that is already charged and ready to be taken by the driver.

Once arrived at the charging station with an empty-battery car "A", the driver:

- localizes the recharged car "B" and park car "A" next to it
- transfers the CHAdeMO connector from car "B" to car "A" and starts the charging
- uses its RFID card to access car "B" and drive away, this confirms that the driver completed the swap

The centralized dispatch systems will then monitor the quick-charge progress on car "A". The car "A" being charged to 80% in 20 to 30 minutes, it will then become the "recharged" car available for another swap with another driver in another empty car.

Such a car-swapping process is usually completed in 2 to 3 minutes by most drivers. Of course, the taxi-duty downtime associated with charging events still includes commuting to and from the charging station between customers, but this method reduces the operational charging time from 20-30 minutes to only 2-3 minutes.

Charging threshold and algorithm

Ultimately, decision to charge is not up to the driver's range-anxiety or the dispatcher's judgment. While the team is still working at fully automating the process of charging optimization, the governing principle is rather simple. The following rules are constantly applied to the pool of cars by the centralized backbone system:

- Each time a customer's trip has to be dispatched to a car in the pool, the systems ensures that:
 - i. The car nearest to the customer has a range that is sufficient to, at least, complete the trip requested by the customer and drive to the nearest charging station afterward.
 - ii. If not, the trip is given to the second nearest car that meets the range requirement for the requested trip distance.
- If a car's SOC reaches the *Threshold* level, it is sent to a nearby charging station for a car-swap.

- The *Threshold* level is based on various variables, such as empirical range data for each car model, current weather, predicted overall fleet's SOC, time of day, number of cars in service, etc.

Some other mechanisms are also in effect to avoid getting too many car-swapping requests at once in peak period of the day.

6 What has been accomplished so far

6.1 Gradual deployment of the fleet

Being a pilot project started from ground up, Taxelco taxi service was gradually built, one component at a time

6.1.1 Infrastructures, charging stations and service center

On day one, the first infrastructure need was to establish a service and operation center, in a location that was easily accessible yet “parking-friendly” for the whole initial fleet preparation. This center was equipped with enough office space for hiring, training and hosting of the complete team being assembled. Coordinators, dispatchers, HR, trainers, engineers, mechanics, IT, product development and managers had to have a roof over their heads to start this endeavor. This service center was prepared with sufficient office space for operation-supporting staff, along with a complete garage space, with 2 car lifts, car wash, air compressor and tools. The service center is also hosting the 20 level-2 charging stations and 2 level-3 50kW quick-charging stations.

6.1.2 Training of drivers

Each of the current 75 drivers of the fleet had been trained and coached to acquire the basics of electric cars, to ensure energy efficient driving as well as learning Taxelco car-swapping method and overall dispatch system functioning. With new aspects such as regenerative braking or dealing with the acute torque curve of a 90D Tesla, drivers had to be prepared to embrace this new experience. Taxelco's fleet is far from the usual Toyota Camry taxi car. Being generally informed about EV also made drivers proud to be part of a new movement and prone to answer the basic questions that may arise from their tech-savvy customers.

On human scale, drivers also had to be trained and informed about the new reality of becoming an employee driving a company fleet car. Compared to their past, being self-employed, many of them driving their own car, this new situation brings a new set of rights and responsibilities.

6.1.3 Building of the fleet

Equipping Taxelco's three models of EV was no simple task for the two newly-hired tech-friendly mechanics. Under supervision of IVI's support engineer and equipment providers, they had to rush to equip and connect all cars with:

- Independent auxiliary 12V supply fuse-box
- Driver's dispatch terminal communication hub (8" tablet and mount)
- FleetCarma datalogger box with antennas
- OpenFleet vehicle access control box along with RFID reader and antennas
- High speed LTE wifi accesspoint for passengers
- Taximeters
- Card payment terminal
- Custom designed large roof-mounted taxi dome

At the same time, 50 of the fleet cars were also vinyl wrapped in company's distinctive colors and logos. And by the time everything was shiny and ready to hit the roads, it was already time to lift and remove all 60 cars' wheels to swap tires for winter-worthy ones that are now mandatory in Québec since 2014.

6.1.4 Ramping fleet driving and taxi service with customers

Starting in October 2015, as the drivers were hired and trained and as the fleet cars were wrapped and equipped with all onboard equipments, road-ready cars were gradually put on the road. While first trips were empty ones used for running, they soon became internal trips for Taxelco's staff, then partner companies' staff, then first beta-testers customers. While the fleet operations are still ramping up, Taxelco is hiring new drivers each month. From one shift on a 5 days a week schedule, the team has now successfully added night and week-end shifts and is operating the EV fleet 24/7. This increasing capacity allowed the business to offer its services to more and more customers each month, via its mobile application.

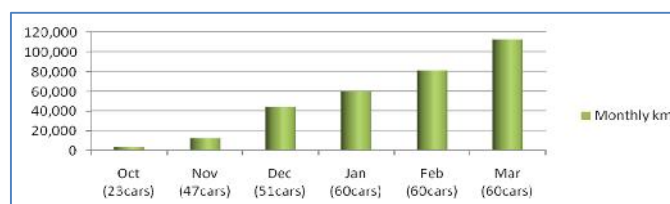


Figure 4: Distance driven by the fleet each month - extracted from FleetCarma reports

6.2 Lessons learned

During the last 6 months, project team had a priceless hands-on experience of building and operating an EV fleet service. Many lessons have been learned from every day-to-day aspects of this venture.

6.2.1 Car-specific features

EV behavior

Before the first car was even purchased, we knew that taxi-fleet duty was very different than standard EPA testing cycles. We had real-life example and historical power consumption data from the three models of EV we selected, however, we did not know how real-world figures would look like in our very specific application once our own taxi vehicles would hit the streets.

With the new and improved 30kWh battery found in the 2016 Nissan, we were expecting a slight advantage over the Kia's 27kWh, knowing that each manufacturer's marketing team has its own creative way to advertise real available energy. What we found is that, during the first winter we operated the fleet, the Kia Soul EV has the overall lowest energy consumption of all models.

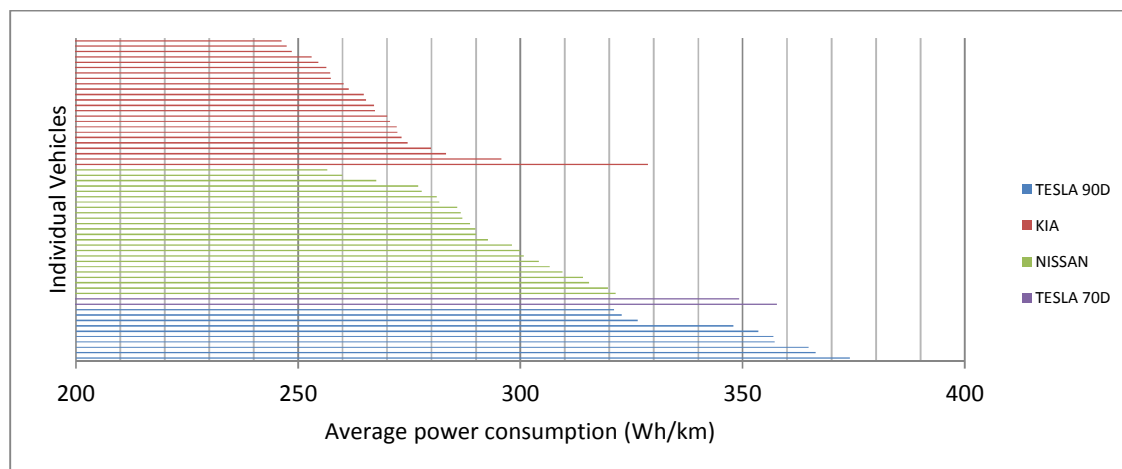


Figure 5: Average consumption of the fleet since first day of operation - extracted from FleetCarma reports

Of course, a complete year of service will add more depth to those numbers, especially with more trips per day and less idle time per vehicle. A few factors had an impact on the previous power consumption figures during the last months. For equipment installation and logistics reasons, our Nissan vehicles are always the latest ones to be taken out of the parking lot. Our Tesla cars are waiting longer between customers, since they

are selected in priority for corporate customers, with longer trips, often outside the regular taxi-service zone, at highway speed. This has a visible impact on average daily distance driven and idle time of the three models:

Table 4: Usage of the fleet, by model – extracted from FleetCarma reports

	Odometer average (km)	Daily average (km)	Idle (%)
Nissan LEAF	3,385	31	63
Kia Soul EV	5,181	55	54
Tesla Model S	7,936	83	75

Body configuration

We found, through experience and customers comments, that even with its shorter wheelbase, the Kia Soul offers the most comfortable taxi-ride for a customer sitting in the rear. The slant roof on the back of the Tesla Model S is synonym of a low seat-to-ceiling height that makes the ride uncomfortable for tall people. This is especially true when the sport-oriented suspension of the Tesla is driven over Montreal's bumpy streets. The Leaf rear seat and suspension offer a fair experience but it does not match the head and knee space found in a Soul.

For luggage hauling, the two-trunk Tesla was an expected champion. On the other end, we discovered that the Soul's tiny trunk volume represent a challenge when customers travel with suitcases.

Styling-wise, in an urban taxi duty, the advanced aerodynamics of the Nissan Leaf and the Tesla Model S provide absolutely no advantage over the boxy Kia Soul EV at 24km/h average speed.

OEM telematics

There was unfortunately no way to connect our central system backbone to any of the manufacturer's telematics interface. Those functions of remote-controlling car locks or HVAC system are only accessible through a mobile app or a web-based interface, and are not aimed at commercial-fleets operations.

6.2.2 Charging

Having many EV drivers in the team, we all globally knew how charging dynamic would be, but we learned interesting details.

- After the high-charging rate portion of a quick-charge, the Kia totally stops accepting energy at 84% SOC, while the Nissan and the Tesla lower the rate (to level-2 rates) and continue taking advantage of the charging station until 100% SOC.
- At very low battery temperature, the Tesla and the Nissan lower quick-charging rate substantially more than the Kia does. On a cold day, this makes a Soul EV charge from 30% to 84% SOC approximately 10min faster than the Leaf.
- At absolute 0% SOC, the charging rate of the Nissan is very limited, making it very long before vehicle can be moved and impossible to quick-charge immediately.
- At very low battery temperature (<-15°C) the charging rate of Tesla's huge battery is very slow, making a CHAdeMO quick-charge impossible.
- Even with a huge 27kWh lithium-ion battery hidden under the floor, a Kia Soul EV will die completely if you do not drive it. Its small 12V 40Ah starting battery (lead-acid and not deep-cycle) will slowly die if the car is not manually started from time to time. This situation does not happen with the Nissan or Tesla, since they periodically turn on their DC-DC converter to charge the 12V battery when not in use.

Charging infrastructure

With such a large armada of charging stations, Taxelco's team had learned many interesting things about commercial-duty operation of those equipment:

- A CHAdeMO station charging connector is a fragile but expensive piece of equipment. It would cost you 3000\$(CAD) to replace if the plastic nozzle gets broken.
- The low current consumption of a Tesla with a cold battery (1 to 5 amps) connected to a networked load-sharing level 2 charging station could be insufficient to trigger that networked charging station to request more current allowance from the "pool-sharing" controller hub. This might cause the level 2 station to

keep its “offer” at 5-6amps on the SAE J1772 “pilot” signal and the Tesla will simply never start charging.

6.2.3 Manufacturer support

With such a large car order of the same vehicle, one fleet owner would expect that manufacturers would give access to documentation and allow some self-service to be performed at the owner’s service facility. This has proven to be a different scenario across all three manufacturers.

Kia Canada offered the best support, providing the diagnostic equipment and documentation to our team of mechanics. This helped the garage team to install equipment and service the cars since day one.

Nissan Canada proved to be a little less pro-active at supporting our service center team. It took many months to obtain diagnostic tools, documentation and related training for our mechanics.

Tesla was less prone to provide advanced support, tools or documents to help our installations and services on the vehicles. We discovered that Tesla has rolled a new version of its entire electrical architecture (changing fusebox numbering and location, etc.) that is not yet documented in owner’s manual.

6.2.4 Human experience

Range-anxiety

The overall experience with drivers, fleet dispatchers and site coordinators that were all new to the world of EV made it clear that range anxiety is a phenomenon that is not only inherent in the average person, but also hard to shake off. In manual operation, beginner dispatchers have a hard time evaluating how far an EV taxi can safely go. We’ve seen dispatchers ask taxi drivers to turn off their car radio at 25% SOC to ensure they would have enough energy to get to destination.

Even with the appropriate training and even if the system is remotely monitoring their vehicle’s state of charge, many drivers keep calling the dispatcher when their car go below 35%, to nervously ask if they should go drive to the nearest charging station.

Winter and EV reality

Montreal taxi drivers are used to drive in harsh winter. They keep their car warm at all time, idling it while in pause, some of them even skillfully regulating the inside temperature by cracking a window open to let enter fresh air. These habits are causing an incredible challenge for operating EVs in winter. Having to wear their winter jacket, turn on heated seats at all time and lower their use of the onboard HVAC system to a 20°C setpoint has proved to be a counterintuitive behavior for most drivers.

Regenerative braking being limited during periods of low battery-temperature, the drivers have to adapt to the changing vehicle behavior while maintaining a comfortable ride for the passengers. For the average ICE car driver, this proves to be a new challenge.

On cold winter days, even with an average daily distance of around 60-70km on 140km-range cars, the quick-chargers are very busy. This day-to-day situation is clearly reflected on the poor power consumption graph.

EV driving experience

We knew that by having Tesla Model S as part of the fleet, we would benefit from the impressive range it offers but we would have to deal with the unnecessary power curve it offers. What we did not expect is how some drivers used to drive the venerable Toyota Camry taxi car would have difficulty to gauge the required pedal inputs modulations to ensure a comfortable ride for customers. The quick acceleration of the Tesla is balanced with an impressive regenerative power braking capability. In the hands of a careless driver, the Model S sets the table for a very unpleasant ride for passengers.

This situation was also observed in the Kia Soul EV, which offers strong regenerative braking (roughly twice the power of Leaf regenerative force while having similar gross weight). Furthermore, Kia’s ECO mode does not smooth throttle acceleration as much as the Nissan Leaf ECO mode does, even if both cars feature an 80kW motor.

Employee vs owner drivers

Car-swapping method involve that a driver will change car at least one time during its shift. This changes the traditional paradigms of usage of a taxi car, where the owner-driver was using the same car for years, having

family pictures on the sun visor and its complete urban-life survival kit scattered around the car. Like a hermit crab leaving its shell for another one, a car-swapping driver needs to travel light, having as little belongings as possible so he doesn't have to transfer everything from one car to another.

Having to access a car multiple times a day with an RFID card, authorizing a CHAdeMO charging session with another card and opening an underground parking gate with a third contactless card is a use case that is far from an ordinary taxi day. Our system bugs are often human-error related even if system engineers try to cover all exceptions.

7 Lab testing

In order to conduct the battery-life study on the EV taxi fleet, IVI's lab team is running tests on a subset of cars representing one third of the actual fleet. By testing the same group of 9 Soul EV, 9 LEAF and 2 Tesla, once per month, IVI is gathering battery capacity data over the 18-month pilot project period.

7.1 Test protocol

Even of the testing protocol and conditions have to be rigorously controlled, the test itself is very simple. It consists at driving a fully-charged vehicle on a dynamometer until the battery is totally discharged and the drivetrain prevents the wheel from moving.

To ensure precision of such a test each month each vehicle has to be prepared following strict guidelines. The EV battery has to be fully charged to 100% SOC, but stabilized overnight in at 25°C ambient temperature after the charging is complete. Vehicle driving tires are changed for a set of regular all-season tires, inflated at the manufacturer's recommended pressure. Vehicle is then anchored to the dynamometer with minimal downforce, in order to avoid any extra parasitic load on the rollers. Prior to the test, all vehicle electrical accessories are turned off to avoid altering the results. Radio, GPS, lights, and onboard devices are turned off to make sure the drivetrain is the only load that drains the EV battery. All ECO-modes and special energy management options are turned off to ensure we run the same test every month. When testing the Tesla, we also have to put the vehicle in two wheel-drive mode, by deactivating the front wheel drive-unit system.

While all these steps and configuration do not represent the real-life usage scenario, their importance is tremendous in the repeatability of the tests and consistency of the results over time. The goal is not to achieve a "real-world distance" on the dynamometer, it is rather to compare the evolution of the "controlled-test distance" over the year and a half of the study pilot project.

The dynamometer itself is calibrated each week using manufacturer's method. Before each test, the dynamometer is run through a warm-up cycle. During the test, the operator has 1 minute to bring the car to 80km/h. The load applied on vehicle drivetrain by the rollers is automatically controlled by the dynamometer, at 20kW (25kW for Tesla). This speed is then maintained by the test operator using car cruise-control system until the drivetrain limits its power at low SOC. At this moment, the test operator takes back control of the accelerator pedal and applies maximum throttle until the wheels stop turning the rollers. The final distance and energy transmitted to the dynamometer is then recorded, along with the complete run log, from 100% to 0% SOC. This process takes around 1 hour on the LEAF and Soul EV and more than 2 hours on the Tesla.

Each step of preparation and testing procedure is part of a checklist that the lab technician has to fill for each test as he performs it on the vehicles of the fleet. This list represents one of the many logs gathered for each test. It includes details such as vehicle's system firmware version number (as this might affect display of SOC and behaviour of the car traction system at low SOC), vehicle odometer, tire pressure, lab temperature, dynamometer calibration parameters, etc.

7.2 Preliminary test results

With only 4 month of testing completed so far on our 20 test vehicles, each car battery capacity has only been measured around four times. While the test results are showing some consistence when comparing vehicles of the same model, it is too early to make any conclusion. The test result fluctuations are currently in the same order of magnitude as the incertitude of our protocol. This is no surprise, if we consider that, at the time of writing, our test vehicles' batteries have only been used for approximately 5000km.

On the dynamometer, the average Kia Soul EV can drive a distance of 82,3km in our controlled test parameters, while the average Nissan LEAF drives 85,3km before stopping:

On the datalogger side, the average total useable battery capacity during the test cycle is 25,1kWh for the Kia Soul EV and 27kWh for the Nissan LEAF:

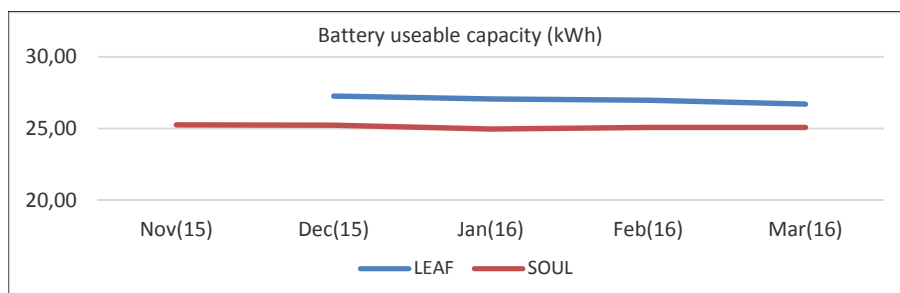


Figure 6: Useable battery capacity during dynamometer tests – average per model

8 What future holds

Of course the project is still at its first months of operation and the cars only have an average of 5000km on the odometer, but it represents the groundwork for a true empowering initiative where a lot will be learned, on all aspects. By the end of the 18 month pilot project, each car will have been driven 100000km and observations on battery life will be possible, helping fleet managers to determine if the actual car models of the fleet are a good choice for sizing up to a 2000-car fleet.

Lessons learned each month will help developers to refine and optimize the algorithm allocating cars to trips and dispatching them to car-swapping stations. A forthcoming partnership with École Polytechnique de Montréal will be working on that area in the next few months.

Taxelco's influence and mutual trust with its various partners is constantly reinforced based on mutual feedbacks drawn from operations. This should allow the developers team to improve the flow of operations, by simple simplifications in the system architecture. This would translate into improvements that would lower the risks of human errors, such as unifying all RFID identification card systems into one, or remotely-authorizing a charging station for a specific car based on its proximity.

Taxelco team is also waiting impatiently to try and test newer EV car models in the next year of the pilot project. New models will bring new learning and will, ultimately, help the team to draft the list of features that would represent the optimal "ideal" taxi car configuration.

9 CONCLUSION

In this time of great effervescence in electrical transportation in Québec, Taxelco is actively part of the EV movement. Efficiently launching its EV taxi service in a time where the taxi industry is also in mutation, Taxelco team already started to gather interesting learning and data from the first months of winter operation. Constantly adding more drivers and customers to its daily flow of activity, Montreal's growing EV taxi fleet will help Taxelco and IVI to establish the patterns of use and gather precious data. This will lead the project team to a more efficient operation of its actual and future fleet of cars. With partners in the industry, Taxelco is looking into possibilities of an eventual partnerships to develop an optimal taxi vehicle platform. This would not only be useful for the company's own fleet growth, but would also be available for other cities to deploy their own EV fleets.

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Authors



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Passionate about cars, Pascal has always been driven by his curiosity to take a hands-on and self-directed approach to extending his multidisciplinary knowledge. He has explored many technical domains and completed an MBA. Pascal has worked in systems engineering since 2002, with practical experience ranging from composite materials to embedded IT, from PCB techniques to MIG welding. He has applied this scope of expertise to interfacing the multiple and contrasting aspects of projects while working, notably, in EV development teams at Nova Bus, Lito Green Motion and now at the Innovative Vehicle Institute.



Thierry St-Cyr ,eng.

Engineer, graduate from Université de Sherbrooke, Thierry has been project manager at Motorola (2001-2006), Member of federal Parliament (2006-2011). He was then Chief of Staff for the Ministry of Transportation, of Municipal Affairs, Regions and Land Occupancy (2012) and for the Québec Ministry of Natural Resources (2013). He then became Director – strategic development at RER Hydro (2014). EV driver since 2012, Thierry has already acquired a strong expertise in electrical transportation. Thierry is now the lead of EV and charging operations, along with public relations at Taxelco, starting a fully electric taxi fleet in Montreal.