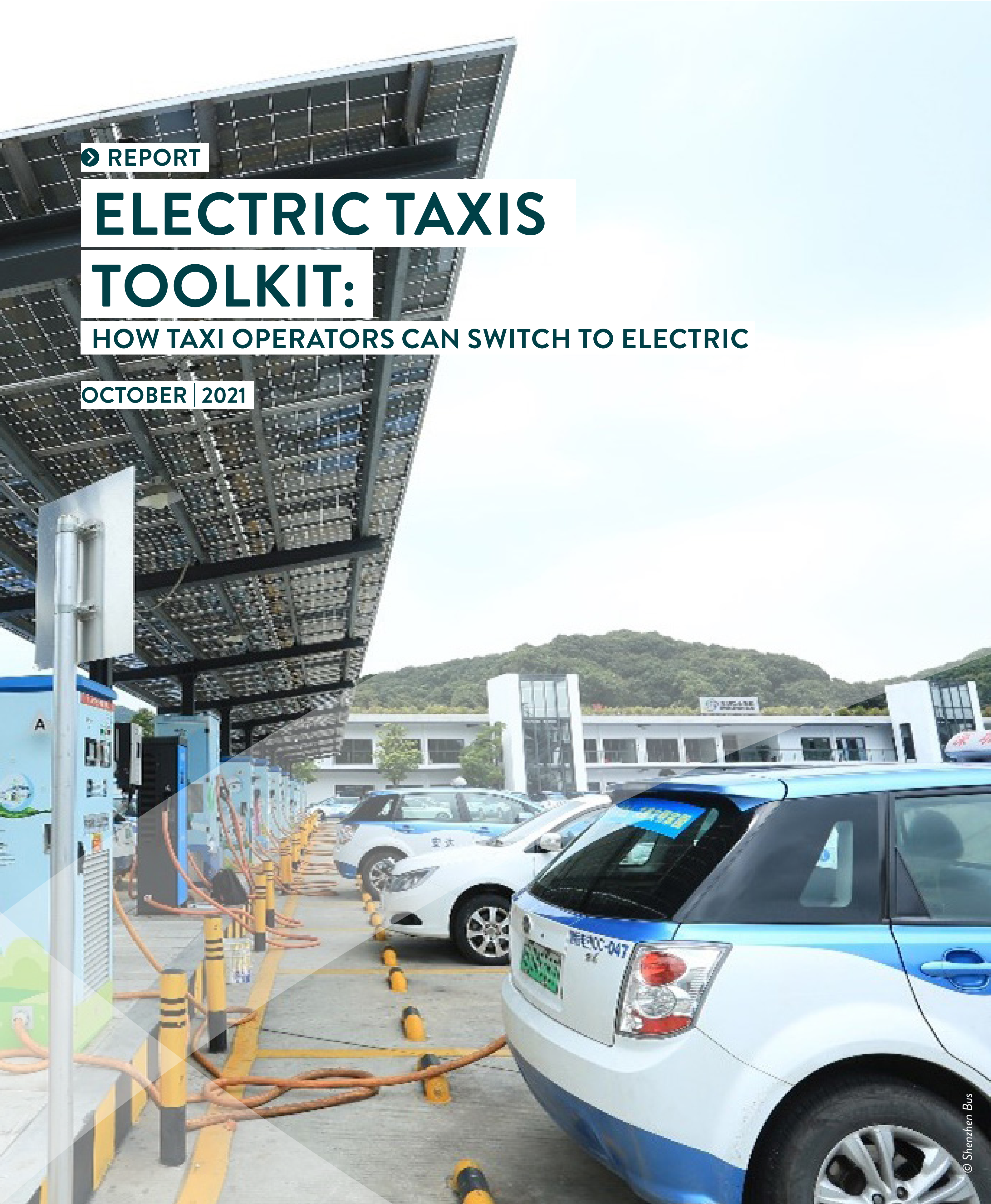
REPORT

ELECTRIC TAXIS TOOLKIT:

HOW TAXI OPERATORS CAN SWITCH TO ELECTRIC

OCTOBER | 2021



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This Report has been prepared by members of the UITP Taxi and Ride-Hailing Committee. Special acknowledgement to Chris Liang (Shenzhen Bus Group) as well as Asher Moses and Martyn Hambley (Sherbet the electric taxi) and Fréderic Pregent (Teo Taxi). UITP staff: Lidia Signor, Arthur Cormier.

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INTRODUCTION

Taxis have the highest energy and greenhouse gas (GHG) emission impacts per passenger kilometre of all urban mobility options[1] and are among the vehicles that register the highest lifetime mileage, especially in cities. Therefore, the sector, cities and people would greatly benefit from a rapid transition to zero tailpipe emission vehicles and notably to pure electric vehicles (or BEV for Battery Electric Vehicles).

In cities, such as London or Montreal, we see clearly demand for cleaner solutions from customers that wish to book electric taxis but also from companies that wish to satisfy their corporate responsibility.

On the private operator side, there is also a wish to switch to electric, more efficient and smart vehicles but the transition is not painless and swift because it implies costs, timely conversion of infrastructure from diesel to the electric new world and basically a big leap into the unknown, which has to be dealt at all levels of organisation.

Observing this situation, UITP decided to mobilise its network through its Taxi & Ride-Hailing Committee to help taxi operators to switch to electric by providing guidelines and examples from the frontrunners, thus as much as possible tailored for the sector.

In this report we particularly dive into the experience of the 'champion' Shenzhen Bus Group and its fully owned subsidiary Pengcheng Electric Taxi running 100% electric taxis.

However, the world of taxis is as wide as transport ranging from big corporations to small businesses, from vertical functional integration to intermediary roles between clients and taxi drivers (the so-called dispatchers or platforms now), from drivers as employees to drivers as independent entrepreneurs. What a taxi operator is includes variable characteristics such as possible ownership of vehicles, facilities, e.g. for maintenance and charging, as well as the interface with the client. And local regulation can play a crucial role, for example in regulating the access to the profession of taxi driver.

That's why, in this report we highlight the experience of a few companies based on 3 different continents and presenting different organisational and business models (simplified as in the table below) to guide the readers towards the lessons learnt and tips that most apply to their specific case.

[1] ITF, 2020. *Good to go? Assessing the environmental performance of new mobility*.

	Fleet	Vehicles	Drivers	Repair & Maintenance	Charging infrastructure	Client interface
PCET (SZBG) - Shenzhen	100% electric	Fully owned	Independent, they rent taxis by shifts[2]	Own facilities and staff	Owned + support to drivers, e.g. through partnerships	Usually through the company
SHERBET - London	40% electric	Fully owned	Independent, they rent taxis for 12h shift or for 52 weeks	Own facilities and staff	Not owned. Drivers can charge at the points available in the market	Clients can book through the company as well as pay by card to it, but drivers can have their own clients
TEO 1.0 (stopped operations)	100% electric	Fully owned	Employees	Own facilities and staff	Owned	Fully through the company
TEO 2.0 – Montreal	100% electric	Partly owned - to be rented long term to drivers that can then buy them	Independent, they can either rent/lease either bring their vehicle	Partnerships with workshops and OEMs	4 charging points + through partnerships and in the market	Clients can book through the company but drivers can have their own clients

In a context where the transition to electric depends exclusively on drivers buying electric taxis, this may require very different actions compared to a context where drivers are able to rent e-taxis from companies that are also providing services such as booking, financial services, maintenance and assistance. In this last case, the company will probably need to finance its transition through a bold step-by-step strategy and a diversification of revenue streams, to minimise the losses and maximise the benefits in a still moving field. In this environment, partnerships and authorities can help, as we will see particularly regarding the charging infrastructure.

However, it is certain that what was looked at as a stable profitable business during a century has become a dynamic space for those that can seize the opportunity. In this context, the

[2] The rental contract is signed by the "Main Shift Driver". This driver usually drives for half a day. If the driver deems it necessary to hire a secondary driver to cover the other half of the day, he is free to do so. All he has to do is to find the secondary driver and have him registered in the company.

main risk is rather to remain still and be left behind. We hope this toolkit will help interested readers to get ahead of the game.

This report will focus on 3 key elements for taxi players:

- **Planning for the transition and operations**
- **Repair and maintenance**
- **Charging**

Figure 1- Electric Taxi in London. Source: Sherbet

1 PLANNING FOR THE TRANSITION AND OPERATIONS

1.1. PLANNING FOR THE TRANSITION

1.1.1. EVALUATION

Prior to any decision to fleet transformation to electric vehicles, it is crucial to review and evaluate the service record and performance of the current fossil fuelled fleet. This should cover aspects including

1. Size of the Original Fleet
2. Drivers' Shifts
3. Maintenance Technician Skills and Qualifications
4. Maintenance Facilities
5. Daily Operation Mileage, Service Coverage and Charging Support
6. Operating Environment
7. Drivers' knowledge and driving behaviour

These aspects must be reviewed and evaluated to guarantee the effectiveness of fleet operation during and after the transition.

1. Size of the original fleet

The size of the existing or original fleet needs to be considered in relation to the post-electrification fleet size, and it will determine if any shift in the labor force (both drivers and technicians) or the management regime need to be changed.

Lessons learnt from Pengcheng Electric Taxis (SZBG)
A similar vehicle size ensured the integrity of the service with a similar number of drivers. In the case of technicians, a decrease in overall workload was envisaged since electric vehicles are more reliable and have less parts compared to a fossil fuel vehicle. Moreover, the three major components (battery, drive motor and battery monitoring system) are under the maintenance responsibility of the vehicle manufacturing with a life-cycle warranty.

Lessons learnt from Sherbet

Having to switch gradually to electric taxis from an original diesel fleet, Sherbet decided to buy 200 electric taxis while disposing of a part of the diesel fleet. The result is that the overall fleet shrank from 700 diesel taxis to 200 electric and 300 diesel. The lesson learnt here is that you need to be ready to shrink before growing. You need to complete due diligence on your assets the full financial landscape as your diesel fleet with devalue and you need to balance this with the Book Value of the vehicle against your balance sheet value of the vehicle. These are all key financial decisions in helping you make the move from diesel to electric.

2. Drivers' Shifts

Drivers' shifts must be carefully considered. Drivers who work in two-shift will need to carefully re-negotiate the shift handover arrangements, because rather than a 5-minute diesel or petrol refill, the current charging technologies will commonly take between 1 to 2 hours to fully charge an electric vehicle.

Lessons learnt from Sherbet

In Sherbet's model where drivers can rent on a long- or short-term basis, it is important to optimise the vehicle utilisation, also to increase booking coverage. In fact, the company offers drivers the opportunity to sign up for its Ride App that connects customers who wish to ride in an e-taxi with e-taxi drivers, being the only app in London to guarantee e-taxis. With this offering of incremental revenue, the company becomes a more attractive package to drivers, and in return this increases the company's fleet utilisation. Additional methods of increasing vehicle utilisation are achieved through online rental platform and enable peer to peer rental amongst drivers. With fast charging becoming more accessible, the LEVC TXE can be fast charged in approx. 45 minutes to enable the vehicle to be ready for the next shift.

3. Maintenance Technicians Skills and Qualifications

The inner workings and components of an electric vehicle is significantly different to that of a fossil fuel vehicle and hence the skills and qualifications of maintenance technicians after electrification also demand new skills sets. Since e-taxis are more mechanically reliable, a maintenance technician will require less mechanical knowledge for vehicle maintenance, but more electrical knowledge. Hence, it is crucial for any operator to have maintenance technicians trained by the vehicle manufacturers before and during the manufacturing of the vehicles in order for them to receive proper knowledge about the vehicle and training on the repair and maintenance process.

4. **Maintenance Facilities**

Figure 2. Facility for e-taxis. Source: Sherbet.

In the transition to electric when still running fossil fuel taxis, as in the case of Sherbet, you need to create a separate space to ensure a safe workflow where only EV trained technician are working. So, you need to turn part of your garage into a workshop and to separate spaces, flows and staff. To scale you will need to consider a new facility and for a new facility you will need to carefully consider the location. The infrastructure of the new site or your existing site needs to be carefully reviewed. For example, the best location is where you can access high voltage electricity, such as near train stations as this enable you to install Charging facilities on site for charging the vehicles.

5. **Daily Operation Mileage, Service Coverage and Charging Support**

Unlike fossil fuel vehicles where a full tank of petrol or diesel will enable a taxi to run for between 400 to 500 kilometres, the latest average electric vehicles will only enable a taxi to operate for 350 kilometres, in SZBG's experience. Moreover, whereas a driver with a fossil fuel vehicle in general do not have to consider too much the geographical area that he/she covers (as they can easily locate a filling station for refuelling), a driver of an electric taxi will need to constantly think and plan the trips since locating a charging station with an available charging terminal might be still not as easy as that of a filling station.

Where do I find an available charging station? Lessons learnt from Pengcheng Electric Taxis (SZBG)

A smartphone app was developed to inform drivers where the nearest vehicle charging stations are. They can also book a timeslot for a particular charging terminal.
On top of building self-owned charging stations, it is equally important to continuous reaching out to external charging station/charger owners to negotiate the usage and price to use their charging infrastructures (see more in Chapter 3).

Due to the nature of an electric taxi operation, the charging stations will need to be built having dispersion in mind. Ideally, an operator (or a city) would want to build charging stations as spread out and close to where drivers live as possible. But as circumstances of each city differ, it could opt for a more concentrated charging station construction solution (See more in Chapter 3 – Focus on charging stations).

In the topic of charging technology, there is a scale to be balanced: the speed of charging and maximising battery life. When charging at a higher C-rate (the battery is charging slower), the amount of heat generated by the large current is proven to be harmful to the batteries, but if a vehicle is charged with a low C-rate (the battery is charging faster), ensuring operation integrity will come with a larger toll in charging station and charging terminal constructions. So, to sum up, in terms of C-rate, it is not the higher the better, and the operator should choose the appropriate charging infrastructure to achieve the balance between charging efficiency and operation integrity.

Lesson learnt from Sherbet

Some electric taxis, like LEVC TX in London, use a range extender that works as a backup for when the battery reaches 2%. The range extender operates to recharge the battery back to 5% and then auto switches off. The range extender extends the range of the battery by driving an electric generator that charges the vehicle's battery. The main benefit of this feature in the vehicle is to reduce the range anxiety of drivers. However, it also produces emissions since it is fuel-based. The emissions are very low with an output of 29g/km which in comparison with a diesel taxi at an average of 222g/km is a significant reduction in emissions. However, the range extender shouldn't be used in zero-emission zones such as in the centre of London. For this reason, a driver needs to carefully consider his/her trips and cities with zero-emission zones should particularly consider building fast charging stations.

6. Operating environment

Before switching to an electric operation, any operator must also take into consideration the local operating environment including physical terrains, traffic situation, weather conditions.

An electric taxi typically weights 2.4 tons which is much heavier than a fossil fuel taxi. Hence, an electric vehicle would generally consume less power on a flat terrain compared to a hilly terrain.

Frequent stopping and starting of a vehicle also consume extra energy, traffic conditions and traffic lights must also need to be accounted for in the overall electricity consumption of an electric taxi.

Extreme weather conditions will affect the battery efficiency of an electric taxi. Cold climatic condition will tend to shorten battery life expectation and discharge cycles[3]. If a battery is charged in cold environment, an irreversible battery life loss will occur, whereas discharging in cold environment will cause a decrease in battery capacity, but this is reversible through charging in warm temperature. In extreme cold conditions, some of the battery could not be charged in a sub-zero temperature. Whereas hot climatic condition will increase the internal temperature of the battery and could yield to higher possibility of short circuit and collapse of the internal supporting structure (usually made of copper), which in turn, could cause potential fire hazard.

7. Drivers' knowledge and driving behaviour

In the transition to drive electric taxis, the drivers have to be accompanied and trained. Regarding energy consumption, for example, drivers might be tempted to reduce the air conditioning or the heating to preserve the battery. However, this behaviour has a negative impact on the comfort and experience of the clients as well as the drivers. If drivers are properly introduced to the e-taxi characteristics and eco-driving principles, they can for example take full advantage of the regenerative braking system that many e-vehicles have. By braking in a certain way, also displayed on a screen, they can regenerate the battery and therefore stop to worry about the air conditioning, for example.

Lessons learnt from Teo 2.0

Facing the challenge to convince drivers to drive e-taxis, Teo taxis established a whole team to accompany drivers and provide them with the necessary expertise, for example on how to manage charging.
The challenge is also somehow cultural and starts before the proper assistance with the recruitment of drivers. In fact, it is difficult for drivers to visualise the long-term benefits of e-taxis as they tend to focus on the day-to-day activity. So Teo's team also helps drivers to see the savings they could make in the long term (e.g. reduction of operational costs, passing from a 50 Canadian dollars in gas per day to 5 Canadian dollars with an EV).

[3] i.e. if a battery started charging when there is 20% left, the process of using the battery to 20% from 100% is call a discharge cycle.

Lessons learnt from Sherbet

In Sherbet's experience it is important that you invest time and effort in training drivers who make the transition from diesel to EV. Drivers are naturally apprehensive of change and moving from diesel to EV also has a number of barriers associated with change. For example, Sherbet's team found that many drivers were concerned about being able to charge their taxi. A dedicated session on vehicle charging from how to charge the vehicle to charging options helps to remove these barriers, especially when you start to talk about the savings of charging against diesel. Drivers' induction sessions are approx. 2 hours long and provide the company with the unique opportunity to train the drivers to have a better understanding of the vehicle they are operating, enhance the wheelchair access training and provide drivers with hints & tips on speaking to customers about the benefits of electric taxis.

1.2 BEFORE RECEIVING THE VEHICLES

1.2.1 OEM TRAINING

Trained technician by the vehicle manufacturers are key when it comes to maintenance crew training. It is quite common for current taxi operators to only train their taxi maintenance crew focusing on the mechanical engineering field. After electrification, the focus shifts, and the staff needs to be re-trained. Training by the OEMs will be beneficial for the maintenance crew to quickly grasp the key knowledge in electric vehicle repair and maintenance.

Lessons learnt from Pengcheng Electric Taxis (SZBG)

After the completion of electrification, and the maintenance crew is adjusted to work on electric vehicle, the knowledge gained from the training process can also be applied to repair and maintenance of external or private electric vehicles, creating a new source of income for the operator.

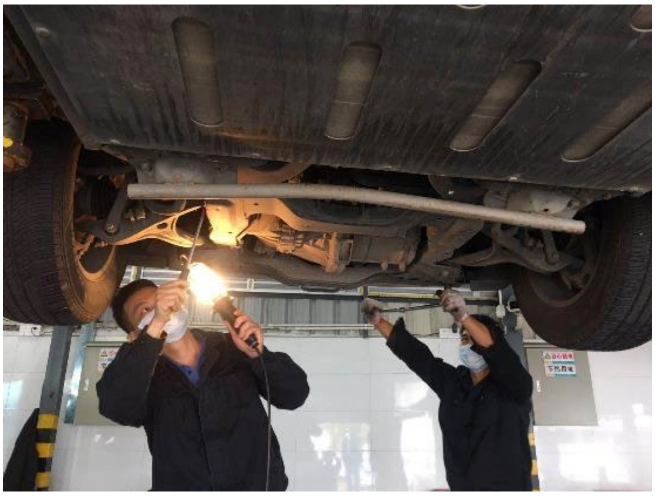


Figure 3- Technicians Performing Maintenance - Source: SZBG

1.2.3 CHARGING TECHNOLOGY UPGRADE

While planning for charging infrastructure, it is important to make sure the charging infrastructure is future proof, as we assume there will be significant continuous technological advancement in charging.

Lessons learnt from Pengcheng Electric Taxis (SZBG)

They are currently using modular DC fast charging technology the most, because of its simplicity in charging terminal to charger management, upgrade and operation efficiency.

Figure 4 - Latest Charging Terminals with Solar Panels Source: SZBG

1.2.4 PEAK SHAVING AND IMPROVED ELECTRICITY UTILISATION

Since the taxi service is part of public transport and part of the city's basic infrastructure, the operator has the responsibility to monitor its impact of the city's power usage. Peak shaving[4] not only serves as a cost reduction practice for an operator, it is also beneficial for the city to normalise the electricity usage. It is recommended for an operator to work closely with the power supplier and the power grid to formulate a mechanism to practice peak shaving in its day-to-day operation.

Lesson learnt from Pengcheng Electric Taxis (SZBG)

They worked with the charging service provider and vehicle OEM in "used/retired battery utilisation". The goal of this project is to provide underground power storage solution for taxi depots and charging stations. This project was inspired by the excess charger resources at certain depots overnight, and under the "Greater Industrial Electricity Price Regime", overnight electricity is the cheapest. Utilising the underground power storage, it has the opportunity to further reduce charging cost.

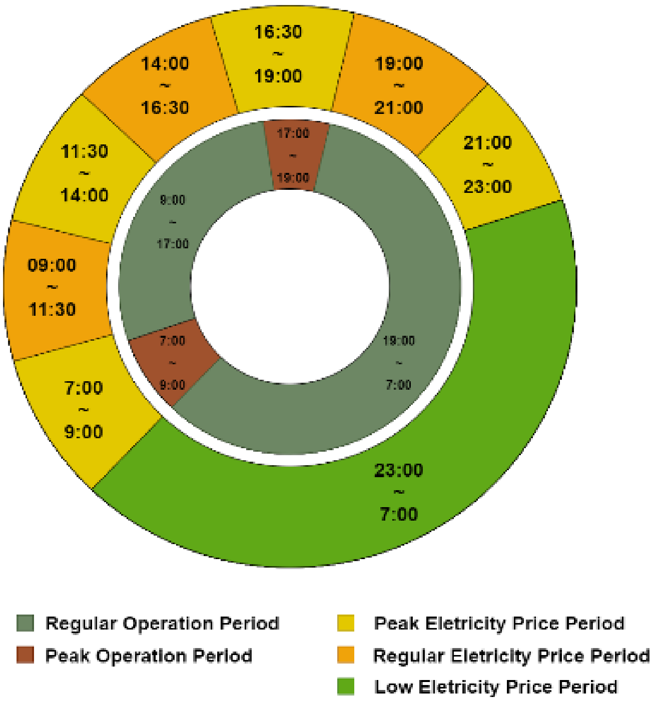


Figure 5 - Scheme showing operation period over the electricity price period: the inner circle is the division of peak and regular operation hours, and the outer circle is representing how the electricity price changes during the day under Shenzhen's Greater Industrial Electricity Price Regime – Source: SZBG

[4] Peak shaving is the exercise to optimise charging behavior so that the energy consumption curve is flatter and bears less load on the grid.

Figure 6 - Power Storage and Distribution Unit - Source: SZBG

1.3 ELECTRIC TAXI OPERATION AND DRIVER MANAGEMENT

After successfully completing electrification, the e-Taxi operations begins. Even though the operation of an electric taxi fleet is quite similar to its diesel counterpart, the differences between the two can be affecting the daily operation considerably and many new opportunities will present themselves with the transition.

First and foremost, in operating a modern electric taxi fleet, key is “intelligentisation” which we can defined as the process to transition operation management from the traditional human-based style to computer and internet-based style. For an electric vehicle, when comparing to a diesel/gasoline vehicle, it is most likely equipped with more advanced computer systems, which will make intelligentisation a much easier transition. It is common for an electric vehicle to have a GPS module integrated into the computer system, a digitised system that communicates through the on-board a Controller Area Network (or CAN[5]) and other peripheral equipment and systems. An operator can simply add a communication module to the vehicle which enables the vehicle’s ability to communicate back and forth with a centralised management system. As operation data aggregates, an operator can forecast repair and maintenance cycle, manage operation on a vehicle-to-vehicle level and apply other smart management tools as it sees appropriate.

[5] CAN is the communication protocol adopted by ISO (ISO11898) and is probably used by the majority of vehicles.

Lessons learnt from Pengcheng Electric Taxis (SZBG)

In Shenzhen Bus Group and Pengcheng Electric Taxi's experience, the first step was to set up an intelligent transport centre. The intelligent transport centre now integrates all data received from individual taxi and generates the following a Vehicle Report, a Driver Profile and a Passenger Demand Report. For more info on the reports, see annexes.

Lessons learnt from Sherbet

The real transition is from "diesel to data", according to Asher Moses, CEO of Sherbet. In fact, with big data, taxis are capable of collecting quality information that can be useful for clients (e.g. booking), drivers (e.g. a charging station not working to be avoided), private partners (e.g. that same charging station not working, relevant for energy providers) as well as city authorities (e.g. pollution or PM rate, pot holes etc.).

1.3.1 ELECTRIC TAXI DRIVER MANAGEMENT

When operating an electric taxi fleet, it is crucial to operate with a robust staff with drivers.

Lesson learnt from Pengcheng Electric Taxis (SZBG)

In order to cope with the newly deployed electric taxi fleet, it updated its driver regulations from its gasoline fleet fitting regulations:

- Shift changing is prohibited during peak hours (07:00-09:00 and 17:00-19:00);
- Drivers sharing the same vehicle should have shift changing time and status of vehicle while performing shift change negotiated and reported to the company in written form;
- All drivers should receive complete electric vehicle focused training before transitioning from gasoline to electric vehicle or employment.

While all other regulations to drivers remained mostly the same, PCET have also reinforced its safety management regulations to enhance the fleet's performance in operation safety, including requirements for passengers to wear seat belts in the back seat, recording risk location and precautions in pre-shift inspections.

Figure 7 - Driver Training Facility - Source: SZBG

1.4 ANNEX

1.4.1 INTELLIGENT TRANSPORT CENTRE OF PCET

Vehicle Report

The Vehicle Report analyses the data collect by the CAN[6] bus and determine the vehicle technology aspects. The key parameters the system focuses on is the operation mileage, remaining State of Charge or SOC[7] and other operational data. These data are then compiled into a vehicle-specific archive and will be available to the maintenance crew to better perform Repair and Maintenance (R&M) work.

Driver Profile is composed automatically with data from the CAN bus and video footage. An AI algorithm is developed to collect driving behaviours in operation, including acceleration, deceleration, power consumption, vehicle location and movement as well as monitoring if the driver has any violation to transport rules and regulations.

Driver Profile

This driver profile will also be used to develop driver-specific training courses to yield better driver performance and achieve more efficient driver's routine training. As the "conclusion" part of the profile, a driver will be given a rating in the following categories:

[6] The Controller Area Network is the communication protocol adopted by ISO (ISO11898)
[7] SOC is state of charge, which represents the percentage of remaining battery.

- Driving skills
  - Maintaining safe distance
  - Regular driving speed
  - Acceleration/Deceleration
  - Attention to road condition
  - Start and stop of each trip
  - Braking
- Driving manner
  - Bad habits
  - CellphoneCell phone usage
  - Smoking
  - Fatigue
  - If the driver is following the previous vehicle too closely
  - Fast lane changing
- Driving Behaviour
  - Seat belt usage
  - Turning
  - Honking
  - Yielding to pedestrian
  - Repetitive mistakes
  - Health
  - Blood pressure

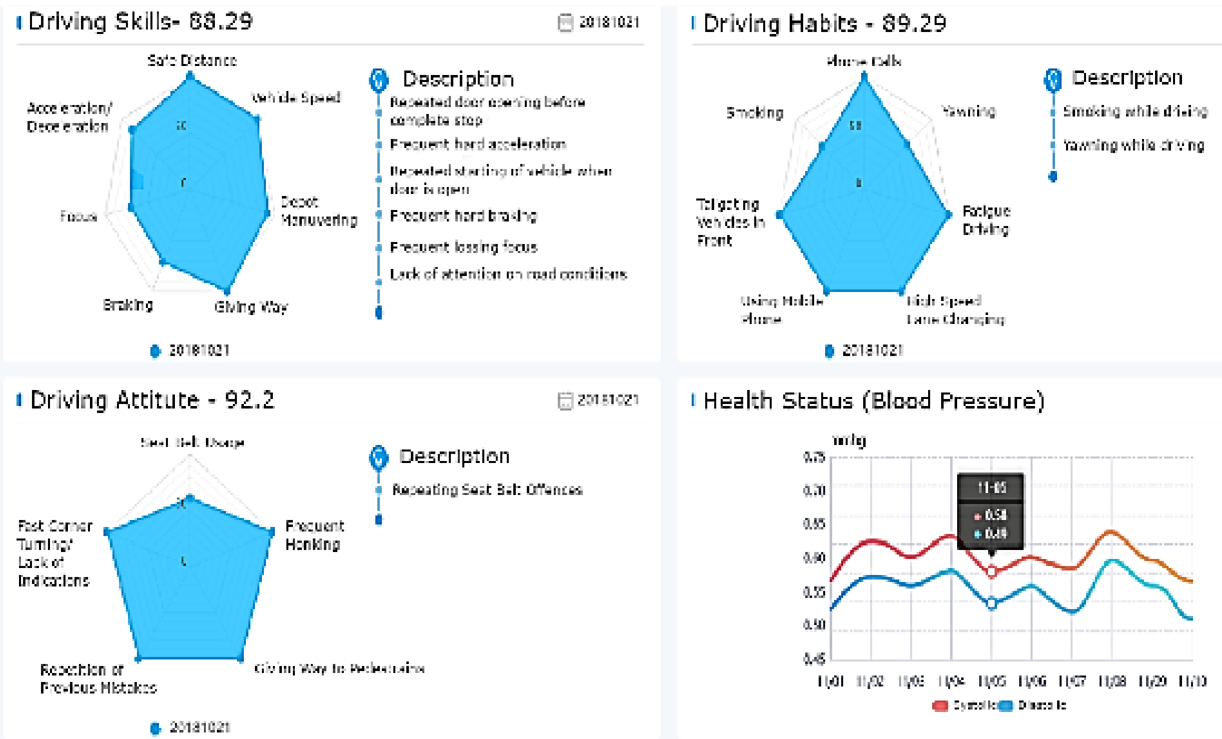


Figure 8 - Driver profile- Source: SZBG

Passenger Demand Report

With big data analysis and a large scale operation, the Intelligent Transport Centre in Pengcheng Electric Taxi can now generate a Passenger Demand Report in which, past passenger data is analysed and compiled into a dynamic heat map for driver's reference. Driver can refer to this map when the vehicle is free to pick up more passengers.

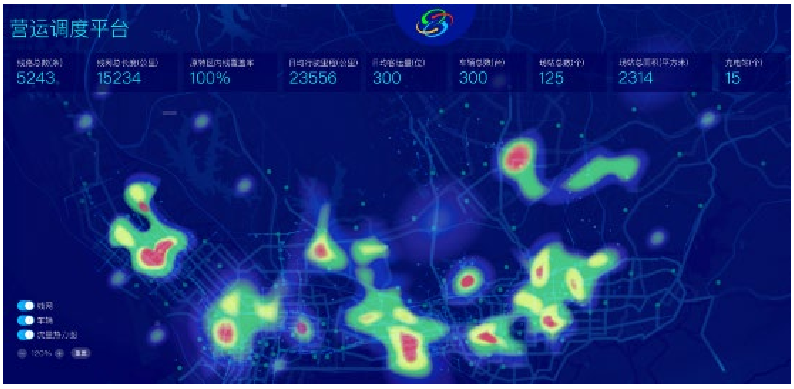


Figure 9 - Passenger demand heat map - Source: SZBG

2 – REPAIR & MAINTAIN

2.1. INTRODUCTION

This second chapter covers the maintenance of e-taxis, that can be outsourced (first subchapter) or in-house, taking from the reputed experience of Pengcheng Electric Taxis (SZBG). In this last case, the chapter covers technical requirements and related processes including the establishment and responsibilities of pure electric taxi maintenance, technical requirements for maintenance and repair, completion inspection, assessment indicators, and management of technical files.

With a fully electric fleet, it is crucial to have the maintenance crew equipped with proper knowledge in electric vehicle repair and maintenance, and due to the improved reliability of the vehicle, the overall workload might be reduced. Thus, an operator with in-house maintenance has the option to make its workshop available to external or private vehicles.

Lessons learnt on spare parts

The experience of different players highlights the crucial importance of spare parts availability in markets where there might be shortage of spare parts. For this reason, a key lesson learnt is to make sure to stock basic spare parts as well as having agreements with concerned OEMs to get priority on the supply.

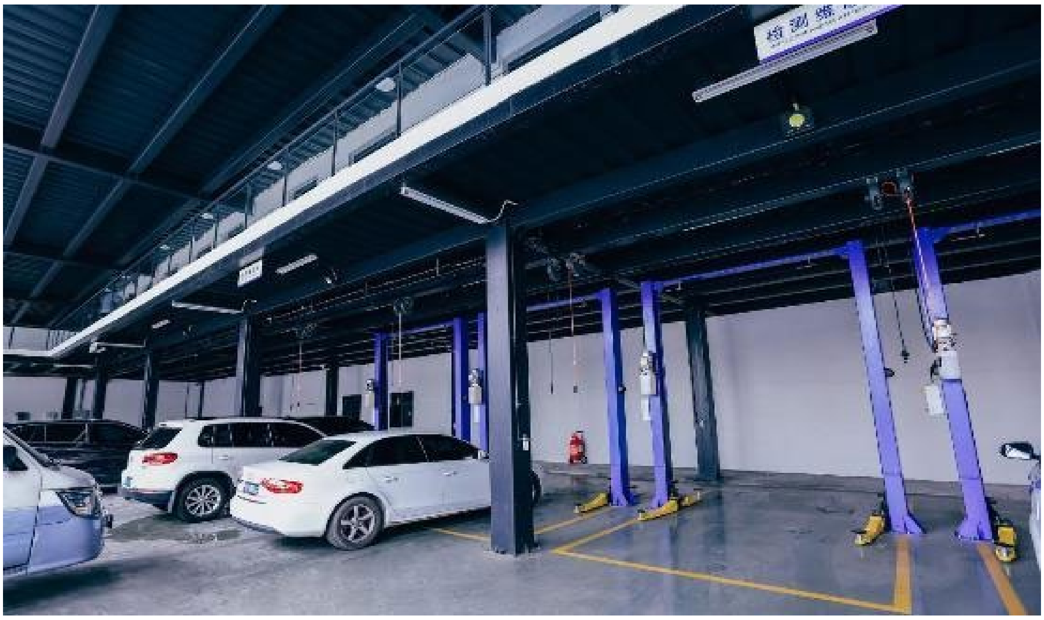


Figure 10 - R&M facility - Source: Pengcheng Electric Taxi SZBG

2.2. OUTSOURCING OF MAINTENANCE

According to the business model of the taxi company, the repair & maintenance can be outsourced thanks to partnerships with independent workshops as well as with OEMs dealerships. In this case, the company needs to rely on the local expertise that have to be in loco. Therefore, it seems a solution for markets where the penetration of electric vehicles is advance and the market size justify the presence of professional workshop.

Lesson learnt from Teo taxis

Teo taxis drew from its first business model, Teo 1.0, the following lesson: to have your own technicians you need to have a critical mass of e-taxis (roughly a few hundreds) or to diversify your revenue streams. In the new Teo 2.0 they established partnerships with workshops for the most recurrent operations and more rarely with OEMs dealerships (that tend to be more expensive).

2.3. IN-HOUSE: ESTABLISHMENT AND RESPONSIBILITIES OF THE MAINTENANCE TEAM

The purpose of this section is to clarify the roles and responsibilities of different parties and personnel within a maintenance and repair facility. Personnel within a maintenance and repair facility shall include Maintenance & Repair Manager, Engineers, Safety Personnel and other personnel which an operation deems essential. These various parties and personnel are crucial to the overall smooth workflow and service integrity of a maintenance workshop. Maintenance organisation shall be included in the electric taxi operation structure. The personnel structure shall include maintenance and repair manager, engineer, safety personnel and other personnel.

2.3.1. MAINTENANCE MANAGER

The responsibilities of the Maintenance Manager include but not limited to the following:

- To fully implement technical regulations, vehicle maintenance technical specifications, and management systems (technical operation safety rules and production safety management system);
- To be responsible for the formulation and modification of rules, regulations, workshop assessment standards and distribution plans:
- To ensure that necessary resources such as facilities, equipment, and personnel are deployed to meet the needs of maintenance and repair work.

Figure 11 - Role and Responsibilities of Maintenance Manager Source: SZBG

2.3.2. MAINTENANCE ENGINEER

The responsibilities of the Maintenance Engineer include but not limited to the following:

To exercise in compliance with all the management frameworks and work requirements, to complete the daily maintenance task on time, making sure quality and quantity targets are met.

- To exercise maintenance technical specifications, technical standards, workflows, to perform self-inspection of maintenance works, to perform puncture repair and maintenance, and to exercise cautions in vehicle disassembly.
- To exercise technical operation safety rules, production safety management system, technical specifications, technical standards and quality inspection system.
- To exercise fire and safety precautions before operation, to operation in accordance with protocol, to locate and report potential safety hazards to the Maintenance Manager
- To complete and pass pre-employment training before employment, to wear proper protection gear according to rules and regulations, and to exercise precaution during operation.

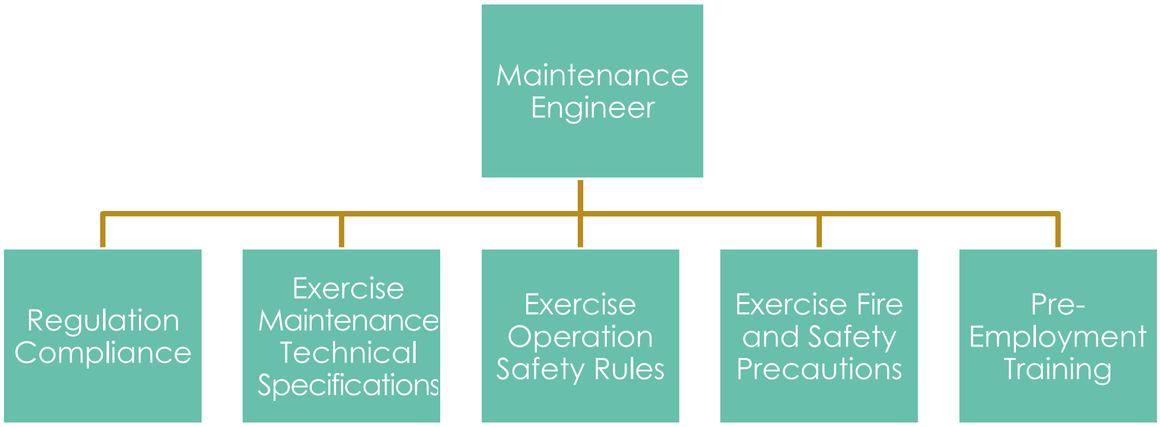


Figure 12 - Role and Responsibilities of the Maintenance Engineer Source: SZBG

2.3.3. SAFETY OFFICER

The responsibilities of the Safety Officer include but are limited to the following:

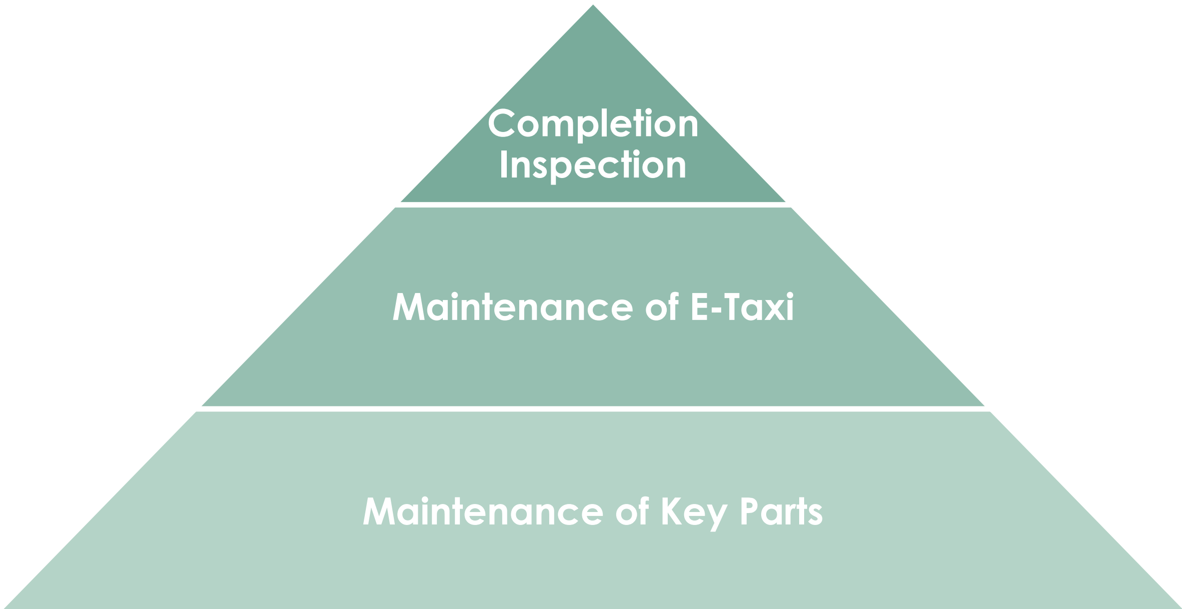
- To fully implement the work safety in maintenance organisations.
- To be responsible for maintenance management, vehicle maintenance site management and insurance reimbursement.
- To perform safety inspection, cleaning, risk monitoring and prevention of the maintenance work area.

Figure 13 - Role and Responsibility of Safety Personnel - Source: SZBG

2.3.4. OTHER PERSONNEL

The responsibilities of other personnel are subject to the specific operation and posts of the maintenance organisation. These posts may include maintenance monitor, quality inspector, warehouse administrator, and post responsibilities and job requirements need to be clearly defined.

2.4. IN-HOUSE: R&M STANDARDS



How often do you need to repair an e-taxi?

In PCET’s experience, major repairs do not happen too often (involving the drive motor, battery and electrical management system), but in the case of other repair work (on the ac unit, lighting, etc.), it takes place without a very predictable pattern.

2.4.1. MAINTENANCE OF ELECTRIC TAXI

The purpose of this section is to define the workflow of maintenance and repair of electric taxis, and it is divided into subsections to further discuss the maintenance or repair processes when dealing with vehicles in different scenarios.

Establishing these technical requirements provides workshops and workers guidelines while performing daily work, which ensure the overall consistency in the quality of work, helps managers in staff management and evaluation, and improves efficiency over time.

General processes for Maintenance of Pure electric Taxi

A. Routine maintenance: Every operation working day (before driving, during driving and after returning), the driver shall perform routine maintenance, including cleaning and safety performance inspection.

B. First maintenance: After the vehicle has travelled for 3 months or 3,000 kilometers, the first maintenance shall be conducted by maintenance professionals, including routine maintenance and changing gear oil in the transmission.

Monthly maintenance: monthly maintenance shall be conducted by maintenance engineers every 8,000-12,000 kilometres or one month. The procedures should include routine maintenance, lubrication and fastening of components, inspection of the system safety components such as the braking system and steering system.

C. Complete maintenance: complete maintenance shall be conducted by maintenance engineers every 45,000-80,000 kilometres or 6 months. The procedures should include monthly maintenance, inspection and adjustment of safety components of the braking system, steering system, and suspension, and overhauling and inspecting tires and conducting tire rotation.

For the specific operation of the first maintenance, monthly maintenance, and complete maintenance of pure electric taxis, refer to Appendix B.

Item	Frequency	Scope
Routine Maintenance	Daily	Clean, Safety Performance
Primary Maintenance	3 Month/3000KM	Changing Gear Greasing
Monthly Maintenance	Monthly/8000-12000KM	Nuts and Bolts, Safety Inspection, Braking, Steering
Complete Maintenance	45000-80000KM	Braking, Tyres, Suspension, Steering

Processes in case of accidents

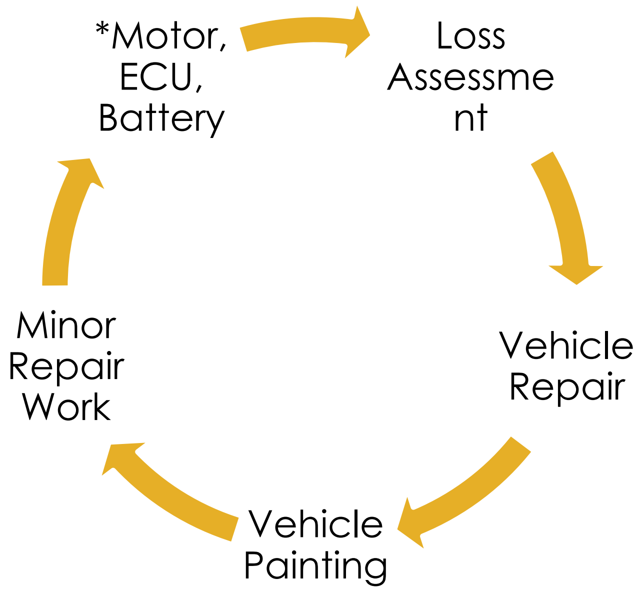


Figure 14 - Complete Vehicle Repair Work Flow - Source: SZBG

A. Loss assessment for vehicles involved in an accident. The loss assessment includes the registration of vehicle malfunction information, the vehicle identification information and , photos to record the damaged parts of the vehicle, and detailed description of the malfunction vehicles. Repair for damaged vehicle will only begin upon the completion of this process.

B. Vehicle repair work: including disassembling damaged parts, classifying and testing the dismantled parts, delivering the spare parts to be replaced to the warehouse, repairing the repairable parts for future use, correcting and repairing the main parts, assembling the accessories and restoring the geometry of the original vehicle. It goes to accident car painting process after the completion of this work.

C. Vehicle painting work: including polishing, de-rusting, cleaning, rustproof treatment, fine filling of tiny holes, coating, varnishing, drying, burnishing, waxing and cleaning of vehicles.

D. Vehicle minor repair work: minor repair work is operational repair, mainly to eliminate any hidden trouble or local damage of the vehicle arising in operation or in maintenance. For specific maintenance operation, see the maintenance manual for the corresponding vehicle.

E. *Maintenance of the "drive motor, electronic control, and power battery":

This process is unique to electric taxi repair and should include the maintenance work of the components of the three main parts which include the drive motor, electronic control, and power battery. The part of the electronic control includes but is not limited to bi-directional inverting charge-discharge motor controller assembly, DC and air-conditioning driver assembly, high-voltage distribution box, and power manager assembly. For specific operation, refer to Appendix A.

Figure 15 - The engine of an e-taxi - Source: SZBG

2.4.2. COMPLETION INSPECTION

A. After maintenance, the quality inspector of the maintenance organisation shall perform inspection and check the key items of the repair or maintenance.

B. The quality inspector shall check every technical performance of the vehicle and conduct road tests. For the items of completion inspection, refer to Appendix C.

C. Vehicles that have passed the inspection upon completion shall be put into operation only after the completion and ex-factory qualification certificate is signed by the quality inspector of the maintenance organisation.

D. If any of the following circumstances occurs in the completion inspection, the vehicle shall not be returned for operation:

- The major maintenance items have not been performed or do not meet the requirements though completed;
- The braking, power, or gliding performance of the vehicle deemed not qualified;
- Signs of vehicle malfunction or abnormal technical condition;
- The main parts or service marks of the vehicle are incomplete;
- The vehicle is not properly cleaned, and the body of the vehicle is still seriously damaged, and affecting service.

Performance Indicators for Maintenance and Repair of Electric Taxis

A. Minor repair frequency

Minor repair frequency of electric taxis is one of the indicators to evaluate the reliability and technical maintenance quality of the vehicle, the unit being times per vehicle per 1000 km. The minor repair frequency of an electric taxi shall be 5% or less. The evaluation method is as follows:

Minor repair frequency = Total of electric taxis repaired within the unit time / Total mileage of the taxis repaired × 100%

Note: Minor repair frequency of a pure electric taxi refers to the quantity of minor repairs per vehicle per 1000 km, which is the quantity of periodic changes completed per unit time.

B. Vehicle return rate

Vehicle return rate of electric taxis refers to the percentage of the vehicles that fails to meet the standard quality or the technical requirements within the warranty period after the completion of the maintenance and repair of the vehicles and need to be dismantled or disassembled to meet the requirements. The vehicle return rate of pure electric taxis shall be 2% or less. The evaluation method is as follows:

The vehicle return rate = (Quantity of vehicles returned for repair per month/Total of vehicles qualified after maintenance per month) × 100%

Note: The warranty for vehicle repair or unit repair shall be 20,000 kilometres or 100 days. The warranty for minor repair and special repair shall be 2,000 kilometres or 10 days. The warranty for monthly maintenance and complete maintenance is 5,000 kilometres or 30 days. The warranty starts from the date of completion of maintenance or repair, and is subject to the mileage indicator or the date indicator, depending on which expires first.

Management of Electric Taxi Repair and Maintenance Technical Files

A. The pure electric vehicle operation organisation shall establish vehicle repair and maintenance technical files, one file per vehicle, one special file per one special vehicle. The content of the vehicle repair and maintenance technical file is shown in the following table.

Table 1 - Electric Vehicle Technical Record - Source: SZBG

Serial No.	Content of Technical File
1	Registration form of the basic information of the vehicle
2	Registration form of the parameters and configuration of the vehicle
3	Registration form of the maintenance and repair of the vehicle
4	Registration form of the detecting test and evaluation of the vehicle
5	Test sheet of the complete maintenance of the vehicle
6	Road transport permit of the vehicle (digital copy)
7	Vehicle driving license (digital copy)
8	Motor vehicle registration certificate (digital copy)
9	Other related materials (digital copy)

B. The technical files of pure electric taxi vehicles shall be managed by specially designated personnel, uniformly classified, filed and recorded, compiled in a standard way, and kept in a unified manner.

C. Dynamic management shall be carried out on technical files of pure electric taxis, and special personnel shall be assigned to make statistics of, collect and update the changed data at the end of each month.

The technical files of pure electric taxis shall be kept for 5 years or more (when applicable). The corresponding file can be destroyed only after the vehicle is scrapped and withdrawn from operation.

2.5. APPENDIX A

(Normative Appendix)

Operating Instructions for Maintenance of the Parts of Drive Motor, Electronic Control, and Power Battery of Electric Taxis

A.1 Confirm that there is no electric shock or ablation on the lug of the drive motor.

A.2 Inspect the 3-phase line bolts at the drive motor end that they are not loose, and the ground is secured.

A.3 Ensure that the waterproof connectors of the drive motor are fastened firmly and that waterproof function works.

A.4 Examine and confirm there is no damage or aging in the bellows of the three-phase high-voltage cable of the drive motor.

A.5 Secure the signal connector of the drive motor.

A.6 Confirm there is no leakage in the drive motor and isn't colliding with other objects, and confirm that there is no crack in the drive motor and all the connecting bolts are fixed firmly.

A.7 Ensure that there is no electric shock or ablation on the input and output lugs of the motor controller.

A.8 Secure the 3-phase line bolts at the output end of the motor controller.

A.9 Secure the waterproof connectors of the motor controller.

A.10Ensure that there is no aging or damage to the 2-phase bus insulation protection and no exposed wire at the input end of the motor controller.

A.11Secure the 2-phase bus bolts at the input end of the motor controller.

A.12Connect the detection interface of the vehicle fault system with the special detection instrument, and read the system fault. In case of historical failure, keep a record before clearing it. Read the data stream and check whether the data meet the standard parameters.

A.13 Inspect (visually accessible part) each ground connection of the DC and air-conditioning driver assembly for looseness and corrosion, if looseness and corrosion is found, perform suitable treatment according to maintenance handbook.

A.14Connect the specialized testing instrument to the system to check whether the DC and air-conditioning driver assembly work properly under high voltage power.

A.15Put the special testing instrument into the system and check whether the input and output voltages of the DC and air-conditioning driver assembly meet the requirements specified in the product specification.

2.6 APPENDIX B

(Normative Appendix)

Instructions for the Maintenance of Pure electric Taxis

B.1 First maintenance

B.1.1 Replace the gear oil of the front drive gearbox after the run-in period.

B.1.2 Examine the integrity and secure that the wheel nuts. There shall be no rupture, bulge, foreign body penetration or abnormal wear on the surface of the tyres, and that the tyre pressure meets the requirements.

B.1.3 Examine the level of brake fluid, steering fluid, antifreeze fluid and battery coolant, and confirm they are within allowed range. Supplement fluid as needed.

B.1.4 Examine and confirm that the quantity and location of firefighting facilities meet the requirements and that the facilities are within the validity.

B.1.5 Confirm the driving brake and the parking brake function properly.

B.1.6 Ensure that the vehicle is tidy and clean inside and outside and that the window glass is complete and in good condition

B.1.7 Inspect the combination meter that it shall display normal remaining power and no report of faults.

B.1.8 Ensure that all gears of windscreen wiper work properly.

B.1.9 Ensure that seat belts are fixed and reliable and function effectively.

B.1.10 Ensure that the headlamp is sound and works properly, its surface is clean, and the near and far lights change properly.

B.1.11 Ensure that the signal light, indicator light and vehicle horn work properly, and their surfaces are clean.

B.1.12 Ensure that the rear view mirror is intact, and that it provides a good field of vision when its angle is adjusted properly.

B.2 Monthly maintenance

B.2.1 In addition to in the items in the first maintenance, inspect the screws, parts and components on the chassis for corrosion, deformation and impact. Ensure there is no leaking or deformation the power motor assembly and the front-drive gearbox assembly.

B.2.2 Examine the anti-collision tube mounting bracket assembly and the battery tray protection plate for bumps and damage.

B.2.3 Examine the brake pedal, electric switch pedal and parking pedal. When the brake pedal is pressed down, there is a sense of power. When the brake pedal is pressed to the bottom and held, it will not relieve pressure. Visually inspect whether there is interference and wear on the harness fastening (visually accessible parts) of the accelerator pedal and the brake pedal; use a feeler to actually measure the stop lamp switch: The gap between the switch and the limit pad is 1-2mm, and the depth of the pedal pad wear pit is less than 0.5mm.

B.2.4 Examine the brake friction block and brake disc. The vehicle has its own friction block wear alarm function. If there is an alarm, check the thickness of the friction block, and determine whether to replace it according to the actual thickness of the friction block. The initial thickness of the front brake disc is 28mm. When it is less than or equal to 26mm, it needs to be replaced. The initial thickness of the rear brake disc is 16mm. It needs to be replaced when it is less than or equal to 14mm. If the brake disc is exceptionally worn, it is better to grind it with the grinding method. However, it can only be ground once.

B.2.5 Examine the brake system pipeline and hose, brake hard pipe, hose, bottom and the four wheels to see whether there is bump or obvious wear, whether there is rust, deformation, whether there is leakage, and whether there is interference with other parts.

B.2.6 Examine the brake pliers assembly (including the guide pin), and check and make sure that the four-wheel brake pliers function properly and are well lubricated. The guide pin grease needs regular maintenance, and the maintenance cycle is every 24,000 km or once a year (which comes first).

B.2.7 Examine the steering wheel and visually examine the airbag modules to see whether there is any damage.

B.2.8 Examine the transmission shaft that it is not leaking oil and whether the rubber sleeve is deformed or damaged.

B.2.9 Examine whether the inside pull rod, left and right outer pull rod and dust cover of the steering gear leak oil, and whether the rubber cover is deformed or damaged.

B.2.10 Examine the front and rear suspension devices and make sure that there is no damage to the front and rear suspension upper arms and the bushing of the front and rear suspension lower arms, and that the front and rear shock absorbers are effective and do not leak oil.

B.2.11 Examine whether the wheel bearings have backlash, ask the driver whether there is too much noise, and determine whether wheel bearings need to be replaced.

B.2.12 Examine the tyres, front wheel positioning and rear wheel positioning, check whether the rims are damaged, deformed or crazes, and make sure that the tyres are free of deformation, damage, and foreign matter and do not wear to the safety line. Rotate the tyre to check whether there is any dragging and whether there is a difference in resistance on the left and right sides of the tyre.

B.2.13 Examine and replace the gear oil in the front drive transmission, the first time within 5,000 km and the next time 24 months or 48,000 km.

B.2.14 Ensure that the level of brake fluid, steering fluid, antifreeze fluid and battery coolant stays between the upper and lower calibration lines. Replace long-acting organic acid-type coolant (battery coolant) every 4 years or 100,000 km; replace brake fluid every 2 years or 40,000 km; and replace steering fluid every 4 years or 100,000 km.

B.2.15 Examine whether there is dust on the air conditioning filter and whether the filter is blocked (tainted at the outlet). Replace if the unit can not be cleaned.

B.2.16 Examine the sub-dashboard body assembly to make sure that there are no liquids, sharp objects or metal objects such as drinks, coins and keys.

Examine the service status of the charging port and check whether there is any foreign object or ablation at the interface of each charging connector. Open the cover plate of the charging port to see whether the cover plate can be supported and check whether there is any foreign matter or ablation at the charging port. If the cover plate cannot be supported, replace it. If there is any foreign object or ablation at the charging port, replace the charging port.

B.2.17 Secure the high-voltage wiring harness or connector, and confirm the pin is not ablative. Secure that the high-voltage and low-voltage wiring harness and connectors, and the wiring harness (visually accessible part) has no interference.

B.2.18 Clean and secure the connection of the positive and negative electrodes of the battery with the wiring harness connection. Examine the color of the battery's indicator, green means the battery is in good condition, black means it needs to be charged, and white means the battery needs to be replaced.

B.2.19 Examine the high voltage components for water marks, open the sub-instrument panel body assembly, and visually check whether there are water marks at the emergency maintenance switch. If there is any water mark, and ensure the battery pack that there is no electric leakage.

B.3 Complete Maintenance

B.3.1 The complete maintenance items include monthly maintenance content and additional maintenance items. Incoming inspection shall be conducted before the complete maintenance. Make fault diagnosis and determine additional maintenance items according to the test results.

B.3.2 Specialized detection instruments shall be used for the incoming inspection of pure electric taxi, including that the vehicle diagnostic system should not have fault information, using road tests to test the driving braking function, checking the four-wheel alignment and tyre dynamic balance, and conducting tyre rotation.

B.3.3 Inspect the sealing of radiator, condenser and pipeline. The radiator, condenser and pipeline are fixed firmly, free of deformation, blockage, damage and leakage. The joint surface of the box cover is in good condition and the rubber pad is not aging. Start the air conditioner, check the high and low pressure pipeline pressure with the air conditioner pressure gauge, judge whether the pressure is normal. For normal high pressure and low pressure, refer to the corresponding vehicle maintenance manual.

B.3.4 Ensure the electric pump functions properly. There shall be no water leakage or noise.

B.3.5 Clean the inside of the front cabin. There shall be no grease, dust or water mark. The front cabin shall be sealed. Check and tighten the bolts and nuts of each mounting bracket.

B.3.6 Adjust the parking brake control mechanism, which shall be flexible and effective.

B.3.7 Secure all the connection lines of the braking device, clean the wheel speed sensor, and make sure that all the connection lines and connectors are free from loosening, rust and burning loss.

B.3.8 Inspect the front cabin and other visible wiring harnesses and wires and make sure the connectors are not loose and have good contact, the wires are neatly arranged and firmly fixed, the insulation layer is free from aging and damage, no wire is exposed wire, and that the wires are firmly connected to the battery pile head and are equipped with insulator sleeves.

B.3.9 Ensure that the steering device is free of crack and oil leakage, each contact ball pin is not loose or worn, the steering is light and flexible, free of stagnation phenomenon, with normal locking and limiting functions.

B.3.10 Inspect and adjust the maximum free turning momentum of the steering wheel. The maximum free turning momentum of the steering wheel shall not be greater than 15° for vehicles with a maximum designed speed of no less than 100 km/h.

B.3.11 Examine the cleanliness outside the whole vehicle, inside the vehicle, outside all the assemblies. The outer bolts and nuts of each assembly of the vehicle are fixed firmly. The lock pins are complete and effective. The whole vehicle is well sealed, free from oil leakage, liquid leakage, air leakage, electric leakage, and water leakage. The on-board diagnostics is free of fault information. All accessories such as rear-view mirror, fire extinguisher, wiper, safety belt are complete and function properly. The road test shows that the driving brake and parking brake performance meet the standards. The vehicle headlamp, signal indicator device and the combination instrument are in good condition and work properly.

B.3.12 Process inspection shall be carried out all the time through the complete maintenance and a record of the inspection shall be kept. The technical requirements of each maintenance operation item in the process inspection shall meet the requirements of the vehicle specification. If the specification does not state the requirements definitely, the relevant requirements of the national standard shall prevail.

B.3.13 After the completion of the complete maintenance of the conventional system of the pure electric taxi, the completion inspection shall be carried out, and the completion inspection record of the complete maintenance shall be filled in. The vehicles that fail the completion inspection shall be further inspected, diagnosed and maintained until technical requirements are met.

2.6. APPENDIX C

(Normative Appendix)
Operation Guide for Completion Inspection of Pure electric Taxis

C.1 Motor

C.1.1 Examine the water tank to see whether there is antifreeze fluid in the water. If there is little or no antifreeze fluid, it must be replenished.

C.1.2 Secure the fixed points of the drive motor and its controller, and check whether the bolts are loose, whether the wiring harness and plug-ins are loose, aging, damaged or corroded.

C.1.3 Examine and ensure the water cooling pipe of the motor body and controller is unobstructed.

C.1.4 Ensure the cleanliness of the motor body and the surface of the controller.

C.1.5 Ensure the motor bearing sounds is normal. When the bearing fails, disassemble the motor and replace the bearing.

C.2 Electronic Control

C.2.1 Ensure the battery is firmly installed, the shell is damaged, the end column wire connector is loose or not in good contact. Inspect the color of the indicator. Green indicates normal, black indicates that the battery needs to be charged, and white indicates that the battery needs to be replaced.

C.2.2 The horn, wiper and other electrical equipment are firmly installed, complete, and work properly.

C.2.3 All parts of the air conditioner are connected firmly and reliably. The air-conditioner has good refrigeration effect with no abnormal sounds.

C.2.4 Ensure all the control functions of the instrument are normal.

C.2.5 Ensure the functions of the lighting system.

C.2.6 Inspect the bi-directional inverting charging-discharging motor controller assembly, DC and air conditioning driver assembly, high voltage distribution box assembly and air conditioner motor compressor work properly.

C.2.7 Inspect the high voltage wire harness and low voltage wire harness for damage and aging, secure the wiring harness plugins and locking mechanism of the high voltage connector.

C.3 Battery

C.3.1 Confirm the integrity of power battery.

C.3.2 Inspect the reliability of high and low voltage connectors and see whether they are deformed, loose, damaged, corroded or sealed.

C.3.3 Ensure the torque of the fixing bolts of the power battery meets the requirements, the standard torque being 95~105N·m.

C.3.4 Ensure the power battery logo is firmly pasted.

C.3.5 Secure the power battery box.

C.4 Braking

C.4.1 Confirm the sensitivity and effectiveness of four-wheel braking, electric vacuum pump, vacuum booster with liquid storage pot assembly and ABS control valve are reliable and effective, free of leakage.

C.4.2 Ensure the vehicle is smooth. The top wheel does not turn loose when rotating.

C.4.3 Inspect the front and rear wheel parts for fracture, and make sure that the screws of each part are firmly fixed and the plugs are complete and effective.

C.4.4 Examine whether the free quantity of the brake pedal is 10-20mm, and make sure that the pedal is flexible and reliable, and the lock pins of the connecting rod are complete and reliable.

C.4.5 Examine whether the service brake is flexible and effective without dragging brake.

C.5 Steering

C.5.1 Ensure that the hydraulic steering device is firmly fixed, it neither sounds abnormally when steering nor leaks oil. It steers with ease and flexibly and returns well. It is free of automatic deviation. The free spin of the steering wheel is 15°-30°. The connecting parts are secure.

C.5.2 Examine the locking nuts between the hydraulic steering gear and the connecting steering parts. The front beam value is 1-5mm

C.6 Tyres

C.6.1 Ensure the air pressure is within safe range.

C.6.2 Ensure the integrity of the steel rim on the tyre.

C.6.3 Secure and examine the integrity of the tyre screws.

C.7 Body

C.7.1 Examine the interior and exterior paint or skin is free of damage or irregularity, and make sure the paint is consistent, bright and beautiful and that the signs are complete and the writing is legible.

C.7.2 Examine the equipment of the carriage is complete and effective, and the seats and lazy-backs are securely installed.

C.7.3 Ensure the door and window switches are functional and the sealing strips are full and complete and free from aging, defect, or water leakage (light leakage) after the doors and windows are closed.

C.7.4 Ensure that the glass of the whole vehicle is free of crack and the door glass lifts freely without any clamping stagnation.

C.7.5 Secure and ensure the integrity of the front and rear bumpers.

C.7.6 Secure the engine room cover and the luggage door are firm and free of deformation and make sure that fastenings and locks are complete and effective.

C.7.7 Ensure the integrity of all parts and that they are reliable and well lubricated.

3 – FOCUS ON CHARGING STATIONS

3.1. INTRODUCTION

This chapter 3 looks into charging stations and how operators can solve this crucial element for their operations:

- They can partner with the government to have the right infrastructure especially in terms of number of charging points, their best locations and power levels
- They can build their own charging stations (see the extensive guidelines provided by SZBG)
- They can partner with private entities to expand the number of available charging points for their drivers and, in case of owning its own charging stations, to diversify revenues as an infrastructure operator.
- They can leave the drivers choose where to charge, especially if the market is well developed and competitive.

Figure 16 - Example of a Charging Station - Source: SZBG

3.2. PARTNERING WITH THE GOVERNMENT TO HAVE THE RIGHT INFRASTRUCTURE FIT FOR PURPOSE

3.2.1. E-CHARGING INFRASTRUCTURE: PUBLIC INVOLVEMENT AND PARTNERSHIPS WITHIN AN EV ECOSYSTEM

It is well-known that local public governments are key stakeholders in the development of electric charging infrastructure, as they can publicly procure, award concessions or grant government support for the construction and operation of recharging points in their territories. Even in the scenario of the infrastructure development being left to the market, their involvement is crucial to maintain network stability, create incentives (not necessarily financial, but more related to access to public space, such as road, parking, city centre) and manage the public space as well as private space through permitting procedures. Therefore, it is important that local government develop a long-term mobility strategy including an electrification and infrastructure strategy to identify needs and fix targets that can also create a stable investment climate.

Cooperation between different government levels as well as neighbouring cities, regions and states is important to align policy measures between authorities, increase coherence between strategies across different policy domains (energy, mobility, housing, etc.) and ultimately reinforce and leverage impact. In China, it is recognised that important and comprehensive subsidies (for manufacturers, operators and charging operators) have pushed the massive transition towards electrification of the transport sector.

In Europe we clearly see that partnerships, not only with energy and infrastructure providers, but also mobility players, such as ride-hailing companies, are strategic to deliver the maximum impact, that we could define as follows.

On the one hand, authorities and concerned stakeholders should aim to provide sufficient availability and capacity for drivers to recharge at their convenience by:

- Defining the required amount of recharging points, taking into account, among others, the expected demand, developments in battery and charging technology as well as new services, e.g. autonomous vehicles
- Identifying the best locations, based on drivers' needs, also data-driven
- Identifying appropriate power levels, where drivers preferences are for both slow and fast charging but for different time and space (e.g. slow charging for overnight cheaper charging near their residence)

For this, an effective partnership with operators and drivers is highly beneficial, thus recommended.

Making charging infrastructure available for all types of electric vehicles (e-buses, e-taxis, e-cars, e-bikes, e-trucks etc.) could be much more cost-effective than standalone infrastructures but this should be done without endangering the provision of operators. In Montreal, for example, taxis drivers would get the priority to charge at Mobility Hubs created by the city.

On the other hand, authorities and concerned stakeholders should also aim to reduce overall deployment costs and nuisance by:

- Making best use of existing infrastructure to limit costs (by making the most of the local grid capacity, for example) and limiting use of public space, especially in cities, to reduce land issues (by agreement with private land owners).
- Maximising the usage rate of the recharging infrastructure to reduce the need for additional recharging infrastructure (e.g. good location and by effective EV parking policy, including stations reserved to drivers for fast charging, for example) and to maximise the return on investment of the infrastructure provider.
- Fostering hardware and software interoperability that can limit the use of public space, avoid technical operator lock-in and give drivers access to an increased amount of recharging points through a single subscription.
- Reducing nuisance during works and during deployment (e.g. queues) and addressing the objections coming from other stakeholders and the wider public[8].

The importance of aligned public measures – The case of Montreal

In Quebec, there are aligned public measures from different government levels to support the acquisition of BEVs as well as the provision of charging infrastructure. So, an e-taxi buyer would get up to 16,400 USD combining both the incentive of the federal government and the provincial government and this is very much welcome as today's schemes generally are not based on the priority of incentivising BEV kilometres rather than BEV ownership, which is what matters for reducing emissions. The city of Montreal has a strategy for the provision of charging points (making also use of public subsidy from other government levels) while companies can also apply to subsidies to install charging points on private land. Finally, the controlled price of the public charging points has a regulation effect on the overall market of charging point fees.

[8] For more information, see *Recommendations for public authorities on: procuring, awarding concessions, licences and/ or granting support for electric recharging infrastructure for passenger cars and vans*, Sustainable Transport Forum, December 2020

The importance of location – the case of London

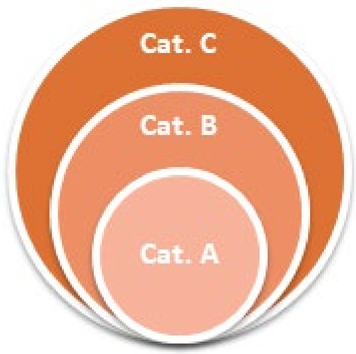
London provides a valuable illustration of a mismatch between the needed locations of public charging infrastructure close to where high-mileage drivers live (if they were to switch to BEVs), and the actual locations clustered in wealthy areas. This happens because most BEVs are expensive and therefore bought by wealthier people. Moreover, drivers are far less likely to have off-street space to install a private charger, contrary to wealthy BEV owners. Thanks to data, Uber partnered with energy and infrastructure companies to place charging station in areas where drivers would use them to charge overnight, resulting in a higher return on investment for the e-charging operators.

The importance of data – the case of Amsterdam

Amsterdam government, in partnership with its contracted charging operators, makes extensive and well documented use of data in planning and managing the charging network. Detailed data allows for an understanding of where BEV driver demand is growing, where new chargers should go and what business approaches are working. New chargers can be located with confidence in areas with the demand to support them, and operated in a way that maximises their effectiveness considering whether there is space and whether the grid can handle it.

3.3 BUILDING YOUR OWN E-TAXI CHARGING STATIONS

The Pengcheng Electric Taxi characterise their taxi stations in 2 categories, from the most essential for taxi operations, the category A to the most comprehensive, including services for passengers and the general public, which is category C.



The number of taxis per depot depends on the size, design of the depot and the mode of operation of the operator. In SZ's case, drivers are not required to return the vehicle to the depot when off-shift, thus, there would just be a few taxis in the depot at the same time unless the fleet has called for a meeting.

3.2.2. DEPOT TYPE A

Stations are generally located at remote outer city fringe areas or occupy small site areas where only basis supporting facilities can be provided for an electric taxi operation. Such basic functions and facilities should nevertheless include vehicle charging and maintenance facilities, resting areas and toilet facilities for drivers as well as a dispatching office. A Category

A Station can be constructed as temporary structure using portacabins and/or containers due to its relatively remote location, limited site area and/or low usage.

Supporting facilities and features for a Category A Charging Station includes:

- connections between depots and roads compliant with local traffic rules/regulations;
- electric chargers meeting with relevant local standards;
- canopies covering the chargers and charging areas;
- a small lounge for drivers to take breaks and rest;
- male and female toilet facilities.

3.2.3. DEPOT TYPE B

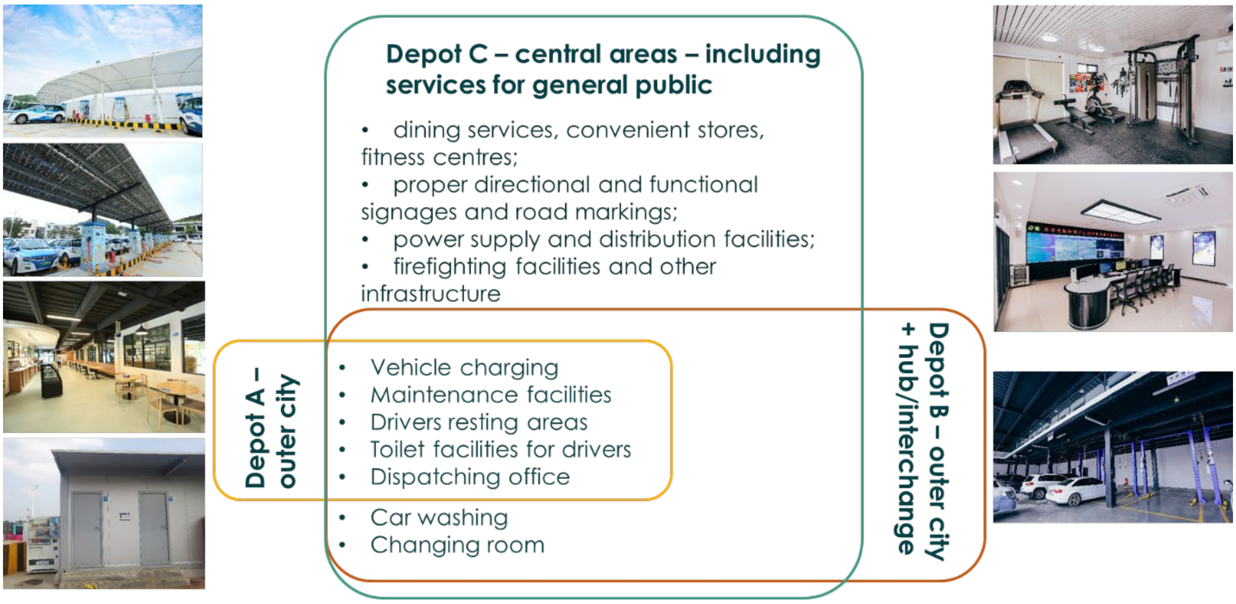
Stations may also be located at outer city fringe areas but at convenient locations adjacent to, for examples, major transport hubs or road interchanges covering more expansive site areas and therefore can provide a more comprehensive range of supporting facilities including all the basic facilities listed for a Category A Station. Similar to a Category A Station, a Category B Depot is one that supports the basic operation of an electric taxi fleet, providing features such as dispatching, drivers' resting area, toilet and changing room facilities, vehicle charging infrastructure, car washing and maintenance facilities. These facilities should be clearly labelled and shown on a floor plan. Similar to a Category A Depot, it is recommended that a Category B Depot should not exceed the features above mentioned, but it is required for a Category B Depot to fulfil all the mentioned features that are included by a Category A Depot.

A Category B Station shall have operation supporting facilities and be located in the city fringe areas.

3.2.4. DEPOT TYPE C

Stations are generally located in relatively more central areas with convenient locations serving not just taxis drivers but also offer services for passengers and the general public. Additional passenger services may include

- dining services, convenient stores, fitness centres,
- proper directional and functional signages and road markings meeting relevant local highways standards;
- power supply and distribution facilities;
- firefighting facilities and other infrastructure.



For more details about the facilities, please consult the annexes.

3.3. PARTNERING WITH OTHER CHARGING STATION OPERATORS

Since the best for drivers is to access convenient charging points when needed without having to go to one of their taxi stations, the SZBG started to negotiate for taxi drivers to access privately owned charging stations, e.g. in shopping malls and business centres. Drivers would benefit from a lower fee, on top of electricity price, to get a similar rate to the one they would have in the company's stations.

As a result of external cooperation, the company, that owns its own charging stations, agreed on having external drivers using its own charging stations (at the same rate applied to its own drivers), which leads to higher return rate for the operator. This can be also a first step in the direction of a business model as charging station operator.

3.4. ANNEX: TAXI FACILITIES

3.4.1. VEHICLE AND PEDESTRIAN ENTRANCES AND EXITS

The design and management of vehicle entrances and exits shall comply with local rules and regulations of transportation, building and fire regulatory bodies. Separate pedestrian entrances and exit shall be provided to minimise pedestrian and vehicular conflict.

Figure 17 - Combined Entrance and Exit (Same Road) - Source: SZBG

3.4.2. CHARGING AREAS AND CHARGERS

Technical requirements regarding the chargers should comply with relevant rules and regulations of fire, safety, environment and power regulatory bodies. The specifications of charging interfaces shall comply with respective local rules and regulations.

In the case of PCET, charging facilities include AC chargers, DC chargers, and other types of chargers are placed and grouped in accessible zones with easy manoeuvring spaces. Parking spaces have proper floor marking and are provided at a charging ratio of 1:1 thus, ensuring the ability to charge each parked vehicle. The width of a parking space is 50% wider than the widest vehicle in the fleet, the length of parking space is 10% longer than the longest vehicle in the fleet, enabling free manoeuvring of all vehicles plus personnel carrying out the charging activities.

The construction of charging areas is not done in low lying areas prone to flooding. For the actual chargers, the base of each charger is raised by 0.2m or higher above the ground to avoid potential hazard caused by flooding, and crash barriers are installed at each parking space to protect them.

Figure 18 - Chargers - Source: SZBG

3.4.3. CANOPIES

To protect charger areas and charging vehicles from the weather as well as falling objects, canopies are recommended to be provided for all charging stations. The width of canopies shall be sufficient to cover the entire charger and the height shall be sufficient for vehicles to move in and out of a space.

Canopies can be in the form of a light weight membrane structure and where appropriate in the form of metal roof where photovoltaic may be installed.

Examples of the two types of canopies adopted by Pengcheng Taxis are shown in the following figures:

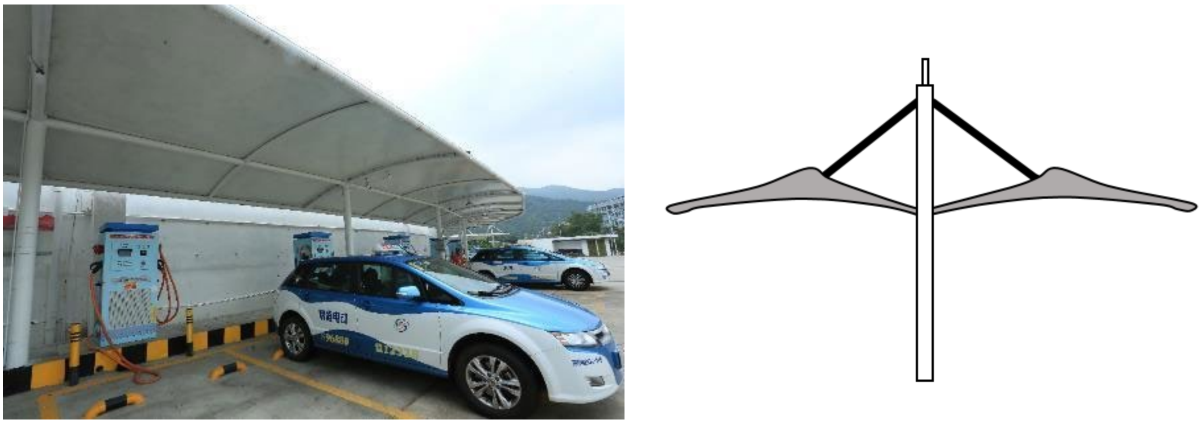


Figure 19 - Picture of a one-sided canopy (left) and drawing of a double-sided canopy (right)- Source: SZBG

Canopy construction shall meet the following requirements:

- The main structural frame shall be solid and robust enough to resist against deformation.
- The canopies shall be firm and durable, with strong resistance against sunshine, wind, external force, and deformation.
- Membrane materials shall have robust sealing performance and proper waterproof performance.
- The service life shall be more than 5 years.

Photovoltaic panels and system are recommended to be installed where feasible to harvest solar energy to supplement electricity supply and as environmentally friendly green features.

The design, construction, and management of canopies shall comply with local rules and regulations of building and fire regulatory bodies.

3.4.4. DRIVERS' LOUNGES

Lounges where possible should be provided for drivers to rest and carry out non-driving work while their vehicles are being charged or receiving services. The size of lounges is flexible and depends on land availability and operational requirements. Lounges shall be equipped with desk top computers, televisions, dining and resting areas and be air-conditioned.

Soft seats and sofas shall be provided in drivers' lounges with the number of seats not less than 80% of the number of chargers and not more than twice the number of chargers. Indoor temperature shall be set properly according to different climatic conditions and seasons.

Figure 20 - Drivers lounge - Source: SZBG

Figure 21 - Drivers facility - source: SZBG

It is essential to keep all supporting facilities tidy and clean. The environmental hygiene quality and management of the supporting facilities shall comply with local regulations and requirements of environment, fire, building, energy, and other related regulatory bodies.

Toilets and Showering Facilities

Female and male toilets and showering facilities should be provided as part of the lounge development for the needs of taxi drivers and other supporting staff. Gender neutral toilets may be considered according to cultural and management acceptance.

Figure 22 - Toilets - Source: SZBG

Figure 23 - Toilets - Source: SZBG

The design, construction, and management of bathrooms shall comply with local rules and regulations of building, fire and health regulatory bodies.

Power Distribution Room

A power distribution room, or power distribution station, refers to a high-voltage electricity distribution device with the functions of power switch-on/switch-off and power distribution, without main transformers on the main power line. Comprehensive charging stations shall set up power distribution rooms.

The power distribution room shall be fenced off and with warning signs displayed on its perimeter. The construction scale of the power distribution room shall depend on the number of chargers and comply with relevant rules and regulations and the design, construction, and management of the power distribution room shall comply with relevant rules and regulations.

Figure 24 - Power Distribution Room - Source: SZBG

Signages

Signages are for easy identification of functional areas or key locations of the charging station on road sides or on walls. For easy identification, the signages shall be install near or directly above of the functional areas or key locations, such as entrances and exits. It is important to design the signages large enough so that it can be spotted by drivers from far, and the recommended size is at least 1.6 meters in width.

To ensure proper clearance of vehicles in the station, the bottom edge of signages shall be 15cm higher than the tallest vehicle in the fleet. It should also be affixed firmly when construct on metal stands, and the stand shall be placed at least 50cm into the ground for enhanced stability.

The design and management of signage shall comply with local rules and regulations of energy, building and fire regulatory bodies.

Examples of signages used by Pengcheng Taxis are shown in the following figures:

Figure 25 - Example of Function Area Signages

Figure 26 - Entrance and Exit Signage

Figure 27 - Charging Station Signage

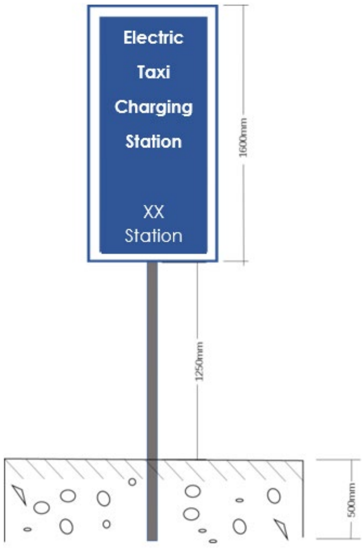


Figure 28- Installation of Charging Station Signage

Management of the charging station

The management of the charging station includes upkeeping the charging facilities and areas, parking areas, office areas, maintenance areas, and all other fleet operation supporting facilities.

It is essential for charging stations to be well managed and upkept with safety of traffic management and handling of high voltage equipment being put as top priorities.

The drainage shall be connected into the municipal sewage network and shall not emit or create pollutant.

The health and safety management of all facilities shall comply with relevant rules and regulations of environment regulatory bodies.

Other services may also be considered by the fleet based on staff and passenger need and traffic volume of the station. Such services may include catering, vehicle repair, car wash, vending machines, fitness and leisure equipment, intelligent transport centre and other services.

Figure 29- Vending Machine

Figure 30 - Fitness Centre
– Exterior (above) and interior (below)

Figure 31 - Intelligent Transport Centre

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