PUTTING ELECTRIC LOGISTICS VEHICLES TO WORK IN SHENZHEN

Vehicle Quality Volume: Identifying Pain Points in ELV Performance that Reduce Utilization

BACKGROUND | POLICY | INFRASTRUCTURE | **VEHICLE QUALITY** | BUSINESS MODEL | SUMMARY

ROCKY MOUNTAIN INSTITUTE

Rocky Mountain Institute (RMI)—an independent nonprofit founded in 1982—transforms global energy use to create a clean, prosperous, and secure low-carbon future. It engages businesses, communities, institutions, and entrepreneurs to accelerate the adoption of market-based solutions that cost-effectively shift from fossil fuels to efficiency and renewables. RMI has office in Basalt and Boulder, Colorado; New York City; Oakland, California; Washington, D.C.; and Beijing.

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MAJOR PARTNERS

Shenzhen Electric Vehicle Operating Association

Shenzhen Electric Vehicle Operating Association engages in six sectors including public transportation, taxi, logistics, rental, charging, and technical services and establishes communication platforms for government and enterprises, organizes industrial investigations and key discussions, develops industrial standards and specifications, and participates in policymaking. It strengthens the integration and cooperation between upstream and downstream players of the new energy vehicle industry chain, and promotes the healthy and orderly development of the new energy vehicle operation industry in Shenzhen.

National Engineering Laboratory for Electric Vehicles

Authorized by the National Development and Reform Commission in 2008, the National Engineering Laboratory for Electric Vehicles was established on the basis of the Electric Vehicle Engineering Technology Center of Beijing Institute of Technology. The National Testing and Management Platform for New Energy Vehicles built by the Laboratory provides data support for the research of new energy vehicles technology and the making of industrial policies.

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As the electric logistics vehicle (ELV) market in China has increasingly shifted from a policy-led development model to a market-led model, the ability of an ELV to perform equivalently to an internal combustion engine (ICE) vehicle has become an area of increasing focus. Users are reluctant to purchase ELVs if they do not believe that they will have both the capabilities and reliability of an ICE vehicle.

In previous volumes of this series, we looked at public sector actions, such as incentives and infrastructure deployment, as levers to improve ELV utilization. In this volume we shift our focus to vehicle performance and technology, providing a brief introduction of the status quo of vehicle performance and the major technical problems experienced in the deployment of ELVs in Shenzhen. We analyzed six major aspects of ELV quality and performance, including:

- Real-life vehicle range
- Degree of battery degradation
- Service life of the vehicle and residual value
- Vehicle failure rate and failure modes
- Vehicle power output and speed
- Vehicle loading capacity and constraints

Furthermore, we identify key technical pain points (e.g., battery degradation, component failure, and loading capabilities) affecting the utilization rate of ELVs and evaluate the importance of those pain points through data analysis combined with interviews. We also suggest pathways to address utilization shortfalls that result from insufficient vehicle capabilities and quality.

Based on this analysis, the research team arrived at the following main conclusions:

1. Overall, ELVs fail at a lower rate than ICE trucks. However, in the absence of a mature repair and maintenance system, ELV failures carry higher utilization penalties. Furthermore, several specific types of failures create high vehicle downtime and safety risks.

2. At present, ELVs in Shenzhen can effectively compete with ICE logistics vehicles in most urban delivery scenarios.

3. ELV battery capacity and range is largely sufficient to meet the demands of urban freight transportation. However, ongoing development of battery technology, especially reduced degradation, and the continuous improvement of charging infrastructure are still needed to ensure that ELVs can compete in all applications.

4. Battery degradation has been a commonly identified issue previously and remains a major problem, which reduces the attractiveness of ELVs as a long-term investment and inhibits the growth of a market for used vehicles.

5. An improved track record of long-term performance is needed to establish vehicle residual value and is critical to grow purchases by fleet owners—especially as subsidization declines.

INTRODUCTION

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SHENZHEN'S ROLE IN CHINA'S EV TECHNOLOGY PUSH

Electric vehicles (EVs) have become both simpler and more efficient than ICE vehicles. This is due to substituting an electric motor and batteries for an internal combustion engine and removing complicated mechanical drivetrains customized for the power output of an internal combustion engine. The elimination of the large volume of auxiliary equipment and fluids needed to keep a complex mechanical drivetrain functioning is another factor that favors EVs.

China's focus on research and development for EVs began in the Ninth Five-year Plan (FYP) period in 1996. That plan gave rise to China's first set of incentives to encourage the development of core EV technologies.[1] As a result, Dongfeng Motor developed China's first pure electric concept car. In the following decade, with investment and support created by the national Tenth and Eleventh Five-Year Plans, EV technology continued to mature.[2]

In 2009, China launched the "10 cities and 1,000 cars" demonstration project that marked the start of its current stage of rapid development of EVs.[3] The demonstration project established China's well-known subsidy policies for EV purchases, but also laid the foundation for the technical innovation projects and EV-related research and development plans of the 12th and 13th FYPs respectively. In those five-year plans, China was able to achieve breakthroughs in key barriers of EV development and catalyze large-scale deployment of EVs.[4]

Among the major pilot cities covered by the "10 cities and 1,000 cars" demonstration project, Shenzhen has emerged as China's leader in EV adoption—especially in the field of commercial transport such as buses, taxis, and logistics vehicles. Given that commercial applications both have higher standards for vehicle reliability than personally owned vehicles and commercial duty cycles are typically more challenging than the duty cycles of private vehicles, the demands in Shenzhen for quality and reliability in EVs has been strong. This role has made Shenzhen a living laboratory where the technology and quality of EVs are continuously refined and improved.

THE CONNECTION BETWEEN ELV QUALITY AND UTILIZATION IN SHENZHEN

Unlike private cars, utilization and productivity of commercial vehicles, such as ELVs, has a direct, measurable impact on a company's bottom line. When a fleet owner is contemplating the purchase of an ELV, vehicle quality metrics such as vehicle and battery life, vehicle range, operational flexibility, and maintenance and downtime costs are as important as capital and operating expenses. However, they are far less analyzed and understood. In this analysis, we focus on several indicators of vehicle capabilities and quality which are key to ELV utilization and competitiveness.

Ability to perform in a range of distribution scenarios and move different types of goods

Not all urban delivery scenarios are the same. In fact, a given vehicle may be asked to carry out a wide array of delivery activities over the course of its useful life. A vehicle's ability to effectively perform those varied tasks is a key element of its value proposition. Such applicability can be analyzed by indicators such as power output and maximum speed, maximum loading weight, and maximum loading volume. The ability to carry specialized goods such as refrigerated or heavy cargo is another important consideration.

Ability to complete a full delivery task

Distribution efficiency is a critical driver of revenue generation for logistics vehicles. The more goods delivered in a given amount of time or a given amount of driving, the more revenue that vehicle will generate. In the case of ELVs, that efficiency may be restricted by its weight and volume capacities as mentioned above. However, a more important differentiator between ELVs and ICE vehicles in terms of productivity is the time lost to charging and wasted driving in the search for charging facilities. Therefore, the main technical indicator impacting the distribution efficiency of ELVs is battery capacity, both initially and as the vehicle ages.

ANALYTICAL APPROACH AND DATA

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To estimate the technical capabilities of ELVs in Shenzhen, the research team took a three-pronged, data-driven approach, which included:

- Collecting descriptive statistics on key vehicle performance metrics and vehicle failure causes from vehicle telematics data
- Estimating vehicle battery degradation through regression techniques based on state of charge (SOC) and odometer data from vehicle telematics
- Benchmarking ICE vehicles and ELVs on several common capability indicators such as maximum load weight and volume, power output, and labeled fuel efficiency

DATA AND INTERVIEWS

Similar to other volumes in this series, the research team paired qualitative and quantitative approaches to arrive at holistic conclusions of ELV performance. However, since vehicle capability is a complex concept that is difficult to capture with data alone, the role of qualitative analysis in this volume was more pronounced than in previous volumes.

The main data sources used in this research are telematics data collected from ELVs operating in Shenzhen in 2018 and 2019 from the National EV Data Platform, as well as vehicle model information published by ChinaCar.com.cn. Key data points from the National EV Data Platform of New Energy Vehicles used in this analysis were battery state of charge, odometer readings, speed, and engine power output. Specific alert information indicating failures of various onboard systems (e.g., high battery temperature, engine failure, and inverter failure) was also used. The data published by ChinaCar includes high-level static data about specific vehicle models including maximum loading capacity, power, vehicle weight, and chassis type.

In parallel with the data analysis, the research team conducted interviews with local transportation enterprises and logistics vehicle operators in Shenzhen. Through these interviews the team gained an in-depth understanding of common causes of vehicle failure, known performance issues, and technical shortcomings that impacted the use of ELVs. With the cooperation and support of Shenzhen Electric Vehicle Operating Association, the research team surveyed enterprises such as DST Vehicle Rental, SF Express, BAIC, BJEV, and others.

KEY ANALYTICAL RESULTS

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In our analytic work, the research team focused on six major indicators of ELV quality and performance. Those were:

- Real-life vehicle range
- Degree of battery degradation
- Service life of the vehicle and residual value
- Vehicle failure rate and failure modes
- Vehicle power output and speed
- Vehicle loading capacity and constraints

In general, the above six indicators have shown continuous improvement over time. However, when compared with ICE vehicles, it can be seen that there is still a gap between ELVs and fuel trucks in some indicators.

1. REAL-LIFE VEHICLE RANGE

Range has always been the most important performance indicator when considering the purchase of an ELV. Due to the limitations of battery energy density, it is difficult for ELVs to achieve ranges typical of ICE logistics vehicles. This limited range often leads to the need for more frequent charging, which directly affects vehicle productivity and utilization. It also increases user costs and hurts ELV's value proposition relative to ICE counterparts.

The range of ELVs usually can be shown in two forms: one is the nominal range declared in the vehicle specifications. This is typically established in laboratory and road tests before the vehicle leaves the factory. The other is the actual range achieved by vehicles on the road. This actual range often differs from the nominal range.

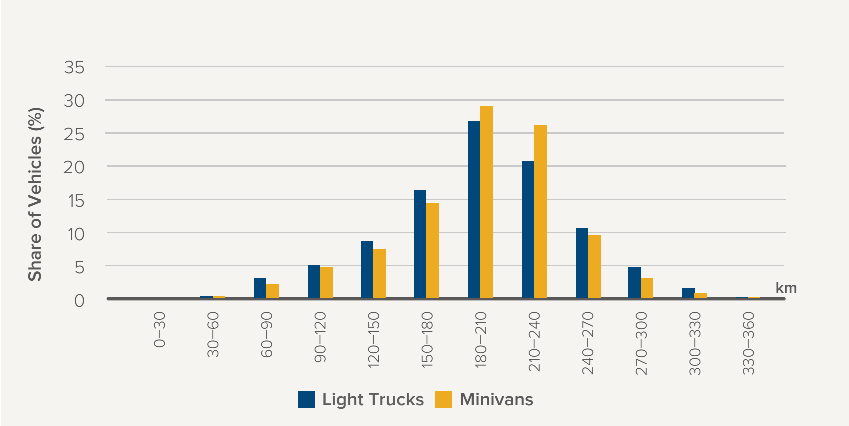
The main reason for this difference is that the nominal range of a vehicle is generally determined according to an assumed duty cycle, which tests the maximum range of a vehicle under ideal conditions.[5] However, in actual driving, urban road conditions, wind temperature and humidity, driving speed, topography, driving habits, and other factors adversely affect the range of the vehicle. Therefore the actual range of an ELV is often lower than its nominal range.

In order to further explore the actual ranges of ELVs and their impact on meeting delivery demands, the research team used information from the National EV Data Platform to estimate the distribution of actual ranges of ELVs in Shenzhen. There are very few scenarios in which a vehicle drives from 100% SOC to 0%, so observing the maximum range is not feasible. In order to estimate vehicle range, the team calculated the actual range of the vehicle by observing kilometers driven from events in which a vehicle drove from 80% SOC to 50% (which occurred on a majority of operational days). Scaling this observed value for kilometers driven when drawing the battery down by 30% of its total capacity to the full battery size gave the estimated range of that vehicle in 2019.

As can be seen in Exhibit 1, the range that ELVs achieve on average is approximately 220 km, although there is a relatively wide dispersion of average ranges of individual vehicles.[6] This range is much higher than both the 70–80 km daily driving distance experienced by ELVs on average (*see Background Volume: Setting the Stage for Full Utilization of ELVs in Shenzhen*) and also higher than the estimated 120–160 km daily driving distance of ICE trucks. Based on this, our conclusion is that ELVs have the ability to meet the needs of most urban delivery scenarios in terms of vehicle range.

EXHIBIT 1

Distribution of the estimated mean range of ELVs on a single charge in Shenzhen, 2019



However, when purchasing an ELV, operators typically do not base their decision on whether or not a vehicle can on average do the job. Vehicle operators demand that a vehicle can do the job even when circumstances are tough.

Examining the variance of achieved range shows that ELVs are not yet able to deliver this full confidence to owners. ELVs in the best case scenario are on average able to drive about 275 km on a single charge (Exhibit 2). However, in a worst-case scenario, the average range of an ELV is only about 160 km—in the range of the average daily driving required of ICE delivery vehicles (Exhibit 3). This relatively large difference between mean range, best-case range, and worst-case range suggests that ELVs are not yet capable of giving operators confidence to fully retire their ICE fleets.

In addition to average range being lower than nominal range, another factor impacts operator willingness to use ELVs for all delivery tasks. ELV users must plan for worst-case range scenarios, not just average operating conditions. Vehicle range is highly sensitive to a number of factors, including vehicle speed; city topography; weather factors, such as wind and humidity; and driver behavior. In adverse conditions that can occur with non-trivial frequency, achieved range can be between 50 km and 130 km below the labeled value.

EXHIBIT 2

Distribution of the best-case scenario estimated range of ELVs on a single charge in Shenzhen, 2019

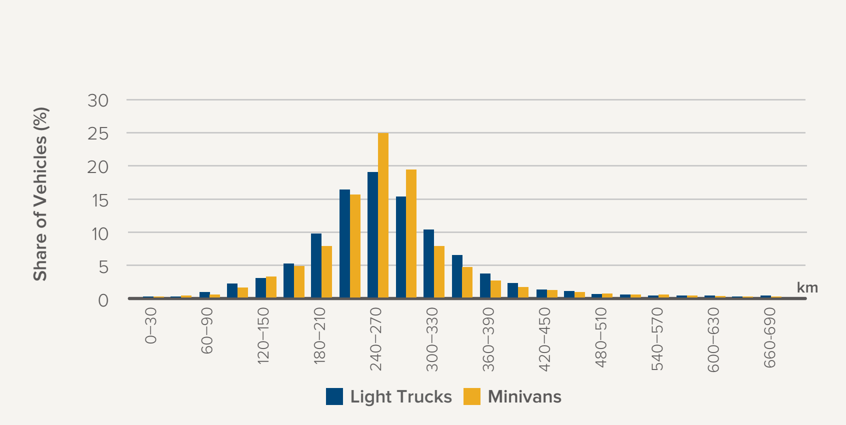
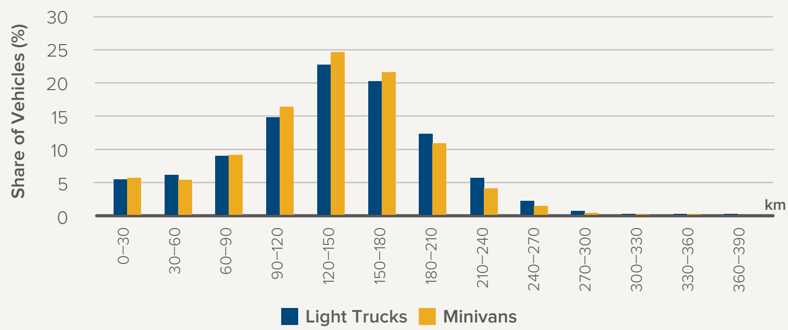


EXHIBIT 3

Distribution of the worst-case scenario estimated range of ELVs on a single charge in Shenzhen, 2019



In order to deal with this unpredictability, operators typically feel comfortable deploying ELVs when the average real-world range of the vehicle is about twice the range required for average daily operations. In most cases, they will only deploy EVs to new routes as the range increases to meet this criteria. This rule of thumb was confirmed through industry interviews and is visible in the charging data over time.

Most vehicles in 2019 charged when the remaining SOC is between 40% and 60%. However, that does not appear to indicate that range is actually twice what is needed. ELV operators' decision to charge a battery when half of its capacity has been used has remained consistent even as vehicle range has risen over the years.[7] In most cases today, ELVs are still mainly used by fleet owners and managers in the mid- and short-distance urban distribution scenarios, while ICE logistics vehicles are still the main vehicles used for longer routes.

2. BATTERY DEGRADATION

Unlike ICE vehicles, the range of an ELV does not remain constant over the course of its lifetime. The extent and rate of this reduction in range is mostly determined by the degree to which its battery has degraded. This phenomenon, which results from chemical changes to the battery from repeated charge-discharge cycles, impacts both the vehicle range and the overall cost of ownership of the vehicles.

There are many factors that can affect degradation of the battery, including battery chemistry, the quality of manufacturing processes, driver behavior, and external factors such as ambient temperature. However, the main determinant of battery degradation is charging behavior, specifically using high-power fast charging.[8]

In Shenzhen, where fast charging has emerged as a major enabler of vehicle utilization, and where battery quality of ELVs is sometimes relatively poor, the degree of battery degradation is high. Actual battery degradation is typically measured with specialized equipment, so a precise estimation of battery degradation is difficult to obtain.[9]

However, based on data provided by the National EV Data Platform, the research team was able to estimate battery degradation by observing changes in kilometers achieved for a given state of charge by a given vehicle on a monthly basis. As the platform has only two years of operational data, the research team extrapolated observed rates of battery degradation into the future to obtain predicted battery degradation over five years of vehicle operation.

Our results suggest that the rates of battery degradation for light trucks is about 8% per year whereas the battery degradation for vans is about 5% per year—leading to degradation of 25%–40% over the life of most vehicles (Exhibits 4 and 5).[i] This is roughly the same as the degree of degradation expressed by logistics companies in interviews. This is primarily due to fast charging, which can lead to chemical changes in the battery that reduce its ability to store energy.

Light-duty trucks experience more alerts from onboard diagnostic systems related to excessive charging voltage than minivans do, which is consistent with their relatively faster battery degradation. We discuss these alerts in depth in Section 4 of this document. As battery and charging management technology progresses, the degree of battery degradation may decrease over time, but under current circumstances, battery degradation remains a top challenge to ELV purchase and utilization.

[i] To estimate battery degradation, the research team took observed mean ranges of each vehicle on a monthly basis and divided them by the best achieved range of that vehicle. That ratio was then indexed to 1. That provided estimated degradation on a monthly basis for each vehicle in the fleet in vehicle-months, calculated from when the vehicle first recorded operations on the data platform, for all vehicles in the fleet bucketed together. The mean value of those buckets is plotted in Exhibits 4 and 5.

EXHIBIT 4

Trend of estimated battery degradation of electric minivans in Shenzhen

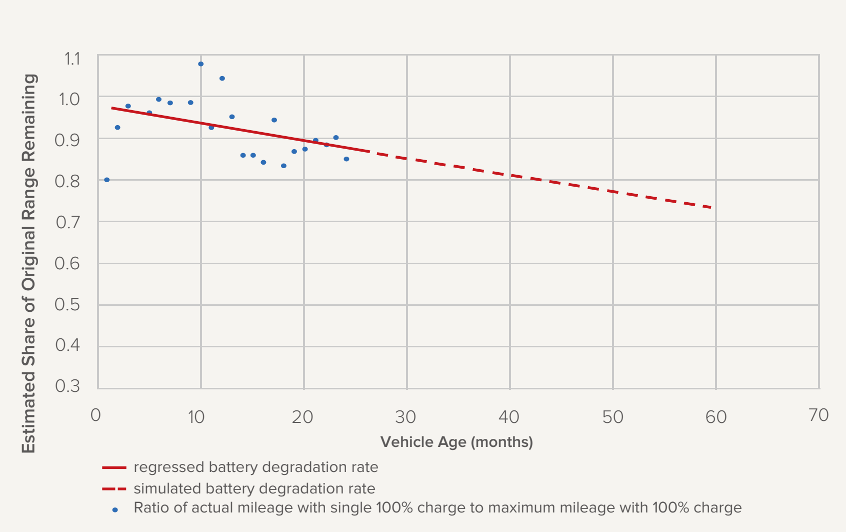
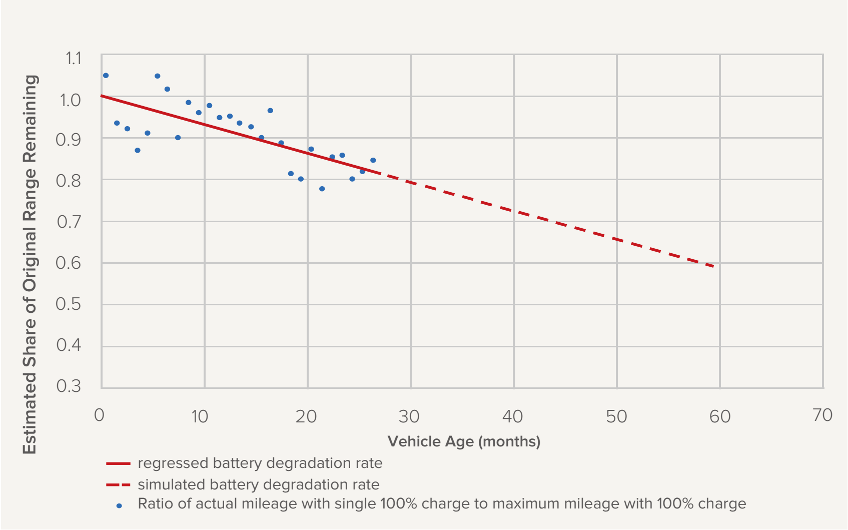


EXHIBIT 5

Trend of estimated battery degradation of electric light trucks in Shenzhen



To manage the concerns this problem creates for ELV buyers, some ELV manufacturers provide battery quality assurance when selling vehicles. Under these terms, if the battery degrades by more than 20% within five years or 100,000 kilometers from vehicle purchase, the battery is replaced free of charge.[10] However, due to the lack of an agreed-upon standard for the evaluation of battery degradation, in many cases disputes arise between the vehicle manufacturer and the vehicle purchaser when free battery replacements are requested. Therefore, the establishment of a standardized, impartial process for evaluating ELV battery degradation is becoming a focus area in Shenzhen.

3. SERVICE LIFE AND RESIDUAL VALUE OF VEHICLES

Battery degradation does not only impact ELV range and operator confidence. It also reduces the value of vehicles in the second-hand market, which is a key element of the value proposition of any vehicle. The service life of most components of an ELV is usually 8–10 years,[11] but the service life of the vehicle is limited by the life of the battery. Typically, once battery capacity degrades by about 40%, an ELV is no longer useful for its original application and the first owner either replaces the battery, an expensive and oftentimes difficult process,[ii] attempts to sell the vehicle, or simply scraps the vehicle. Interviewees suggested that decision is typically made four to five years after vehicle purchase—consistent with our observed battery degradation above.

Batteries that are 40% degraded should theoretically still have some value—either in short range vehicular applications or second-life applications such as stationary storage. However, in the real world they are near worthless and may even cost money to dispose of.

There are two reasons for this very low residual value. The first is that there is no standard procedure for determining the residual capacity of batteries and purchasers do not want to run the risk of paying for a battery that is effectively useless even for second-life applications. Testing battery capacity with accuracy requires expensive equipment operated by experienced workers. While China's Ministry of Industry and Information Technology is evaluating how to build a government approved testing system, no such system exists today.

[ii] For safety purposes, Chinese regulations only allow battery packs in ELVs to be replaced with the same battery pack the vehicle originally came with. After four to five years of vehicle use, those packs are oftentimes no longer available. So rather than buy new batteries, the vehicle itself is often scrapped or sold to operators with use for a vehicle with low range.

The other is that second-life applications of degraded batteries (e.g., stationary storage) are currently limited. These two shortcomings are related, as uncertainty on how much useful life a battery may have after it is no longer suitable for logistics use increases risk for buyers and ultimately lowers demand for second-hand batteries. Partly as a result of this, businesses specializing in second-life battery applications, an area of substantial speculation for quite a few years, have not yet materialized at scale. This results in low demand for second-hand batteries—further depressing prices.

Unfortunately, a solution to supply of second-hand batteries being far in excess of demand for them does not appear to be on the horizon. If anything, the situation is likely to get worse. In the coming years, the number of scrapped EVs will increase significantly, and the price of used batteries will decrease even further—adding urgency to the creation of use cases for second-hand batteries.

4. FAILURE TYPES AND MALFUNCTION RATES OF VEHICLES

Although ELVs have lower failure rates than ICE vehicles, they do still fail and those breakdowns impact utilization. China's National EV Data Platform records component failure information on 19 classes of failures affecting three core vehicles systems (electric controls, battery, and motor).[iii] Common observed ELV failure modes include rapid battery degradation due to high-voltage charging, motor failures, electric control system (e.g., inverter) malfunctions, battery cell inconsistency, and wiring insulation failure (Exhibit 6).

These failures are divided into three levels of severity. Level 1 indicates a minor problem, whereas in the event of a level 3 failure, drivers are prompted to stop driving immediately. ELVs in Shenzhen gave more than 1.8 million malfunction alerts in 2019, however that is not necessarily indicative of how many malfunctions actually occurred. This is because the vehicle will continue to generate an alert every 10 seconds until the problem is addressed. For that reason, the relative distribution of alerts, not their absolute value, is more relevant to understanding potential sources of vehicle failure.

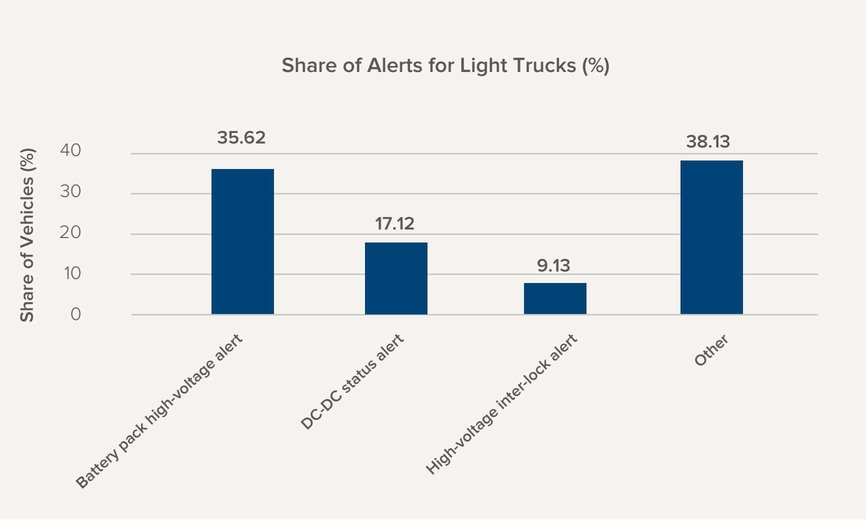
In terms of severity, level 1, level 2, and level 3 accounted for 62.9%, 17.9%, and 19.1% respectively—meaning that only about one in every five alerts (level 3) actually had an effect on vehicle utilization. And while level 3 alerts were viewed as the most important indicator of vehicle quality and were the most likely to produce a maintenance event that impacted vehicle utilization, examination of all events did produce some insights, especially regarding battery degradation.

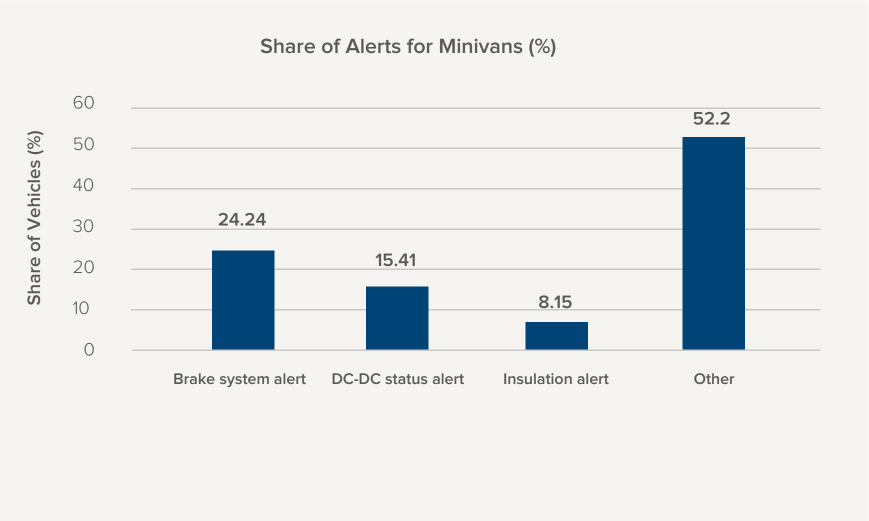
[iii] The 19 classes of failures include: DC-DC temperature alert, DC-DC status alert, low SOC alert, high SOC alert, SOC jump alert, battery overcharge alert, battery over-voltage alert, battery under-voltage alert, cell over-voltage alert, cell under-voltage alert, cell low-consistency alert, high battery temperature alert, high voltage interlock alert, insulation alert, rechargeable system mismatch alert, motor control temperature alert, motor temperature alert, temperature difference alert, and braking system alert.

The alerts (levels 1–3) for light trucks were mostly related to charging behavior. The three most common alerts were battery over-voltage alerts (35.62%), DC-DC status alerts (17.12%), and high-voltage interlock alerts (9.13%), accounting for 60% of the total failures (Exhibit 6). Interviews with fleet owners and managers and vehicle manufacturers suggested that these alerts were caused by charging voltages exceeding maximum values for short periods of time. This excessive voltage likely contributed to the rapid battery degradation in light-duty trucks seen in Section 2 and suggests that the onboard charging system may not be fully protecting the battery as intended.

EXHIBIT 6

Share of each type of failure alerts for electric minivans and light trucks in Shenzhen, all levels included, 2019[12]





Minivans, on the other hand, most commonly experienced braking system alerts (24.24%), DC-DC status alerts (15.41%), and insulation alerts (8.15%), accounting for about 47% of the total failures.[iv] In interviews with fleet owners and managers, operators said that in addition to being an indication of charging at excessive voltage (DC-DC status), these were actually known component failures. This was especially true for certain pumps, bearings in braking systems, and wire coverings which commonly fail with age. This suggests that targeted improvement of certain components in minivans might be able to improve vehicle uptime.

[iv] The third most common failure alert in minivans by absolute number was low SOC alert, but that was excluded as a vehicle failure as it is the ELV equivalent of a low gas indicator.

Looking more closely at level 3 failure alerts, while many of the same problems (i.e., wiring insulation and DC-DC converter problems) exist as in level 1, cell consistency also impacted vehicle life and utilization (Exhibit 7). Cell consistency refers to the degree of consistency between the capacities and voltages of individual cells. In ELVs, as the battery pack ages, the discharged voltages and capacities of individual cells grow increasingly unequal, lowering the overall capacity of the battery pack, leading to the eventual scrapping of the battery.

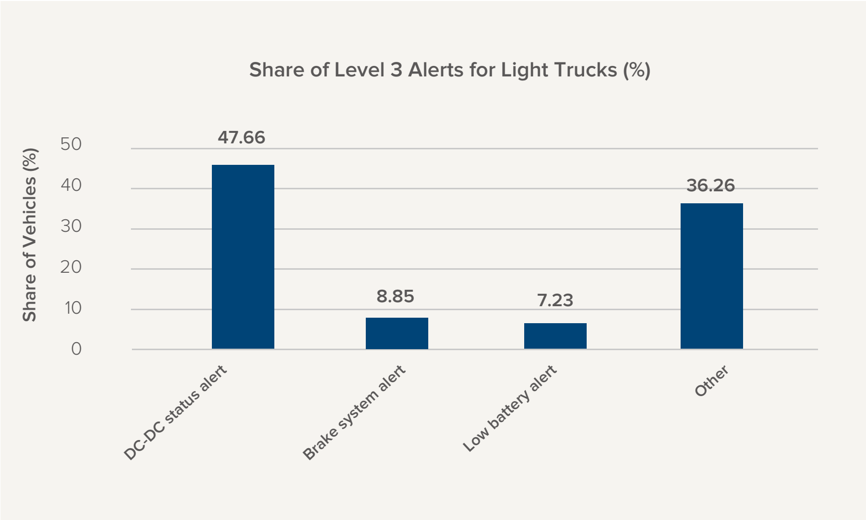
This failure mode suggests that a focus on processes such as battery grouping topology may be able to reduce voltage and capacity disparities and extend the useful life of battery packs. Furthermore, regular maintenance of battery, improved charging management, and improved automation of battery management systems may also improve cell consistency and extend the life of the battery.

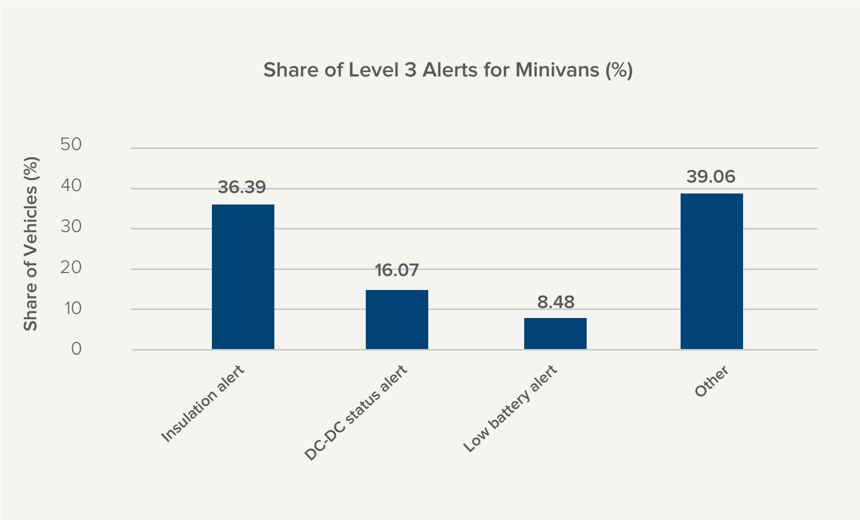
Finally, while high battery temperature alerts were not among the top observed alerts (accounting for only 1.75% of level 3 alerts), they were a major area of focus among fleet owners and managers interviewed due to the possibility of battery fires. These owners and managers mentioned that a level 3 high battery temperature alert usually indicates an advanced stage of lithium dendrite formation, which poses a major risk of short circuits and battery fires. When fleet managers saw this alert, vehicles were immediately removed from service and the battery was scrapped.

According to these fleet owners and managers, maintenance issues caused by both cell voltage inconsistency and lithium dendrite formation caused severe utilization drops. Whereas a typical ELV repair was on the order of 1–3 days and only cost a few thousand yuan, battery-related maintenance downtime was typically one month or more and often required the purchase of a new battery pack. These long repair times were driven by lack of expertise in ELV repair as well as relatively long lead times for spare parts.

EXHIBIT 7

Proportion of level 3 failure alerts for electric minivans and light trucks in Shenzhen, 2019





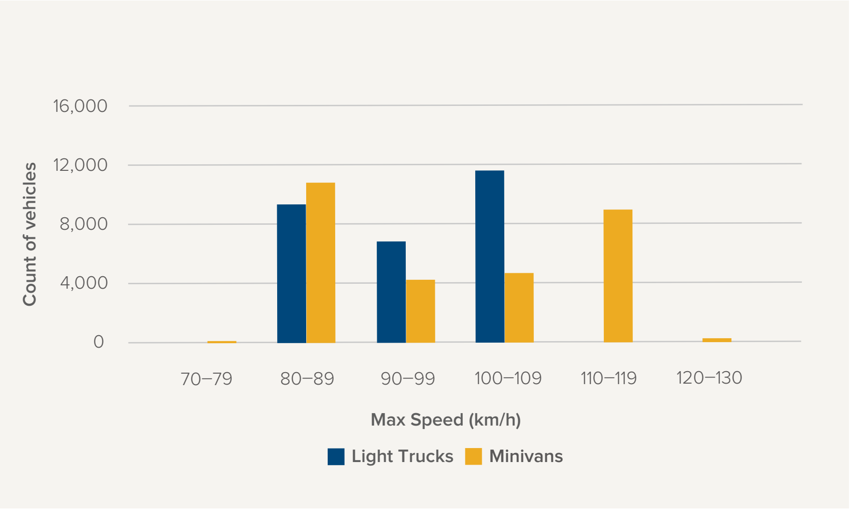
5. POWER AND SPEED

Being able to provide sufficient power to move freight effectively is a fundamental requirement of logistics vehicles. In order to understand ELVs on this metric, the research team analyzed the parameters of top speed and output power of ELVs in operation in Shenzhen based on the vehicle data provided by the National EV Data Platform.

In terms of top observed speed, most ELVs reached 80–120 kilometers (km) per hour. Most interviewees agreed that ELVs were fully capable of those speeds and indicated that they were on par with the top speed of mainstream ICE logistics vehicles, which ranged from 80–100 km per hour. That maximum speed was viewed as sufficient for urban logistics.

EXHIBIT 8

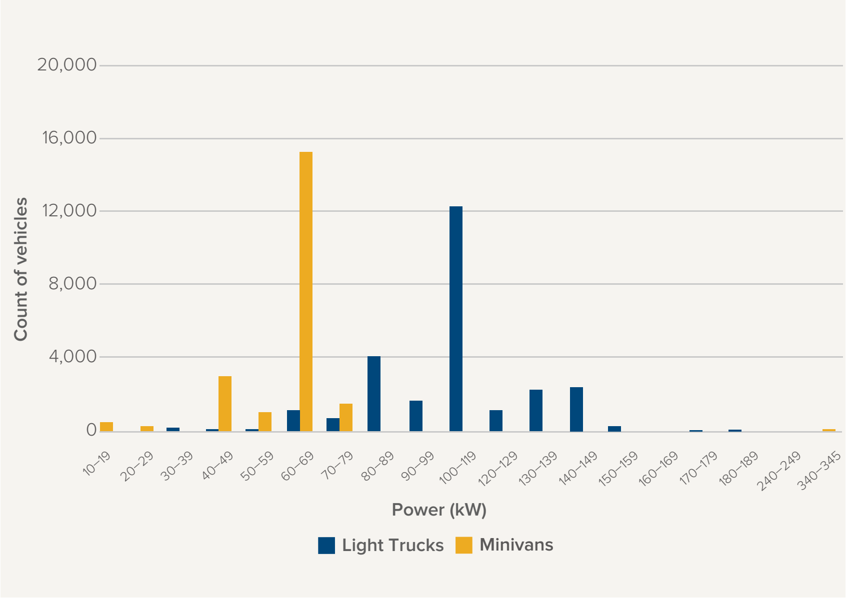
Distribution of top observed speed of ELVs in Shenzhen, 2019



In terms of output power, the maximum power of electric minivans in Shenzhen is concentrated in the range of 60–69 kW, while the maximum power of light trucks is concentrated in the range of 100–109 kW (Exhibit 9). Again, fleet owners and managers stated that such power output was sufficient for urban logistics and often superior to the power offered by many comparable ICE vehicles, especially during acceleration—a known advantage of electric drive trains.

EXHIBIT 9

Distribution of the rated power of ELVs in Shenzhen



6. CARRYING CAPACITY

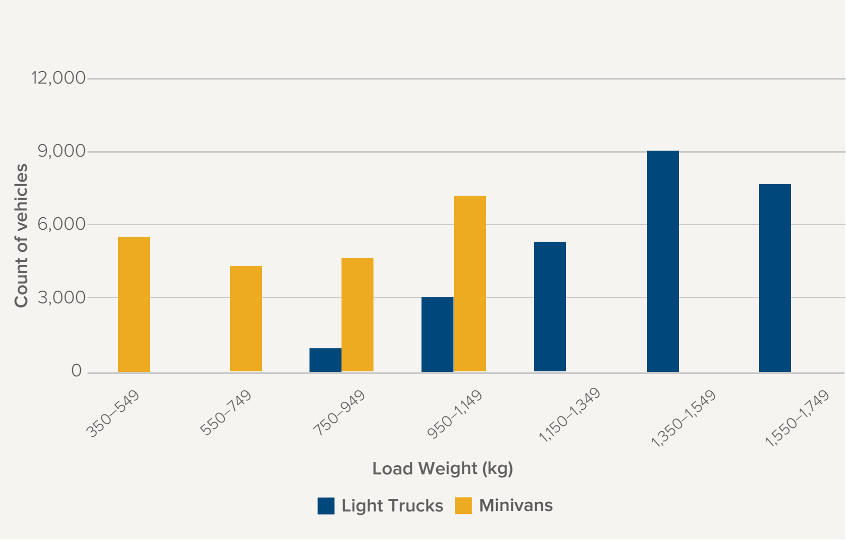
Three elements of carrying capacity decide whether an ELV can fully displace an ICE delivery vehicle: weight, volume, and the types of goods which can be carried.

In terms of loading weight, ELVs must carry batteries as well as cargo. Therefore, the maximum weight-carrying capacity of an ELV is generally lower than that of an ICE vehicle with the same gross vehicle weight.

According to the data from ChinaCar and the National EV Data Platform, we estimate that the carrying capacity penalty is on the order of 10%–20%.[14] The carrying capacity of electric minivans are all concentrated in the range of 350–1,150 kilograms (kg), while those of electric light trucks are in the range of 750–1,750 kg. In contrast, the maximum loading weight of ICE minivans is typically 1,300 kg, and that of ICE light trucks is 2,000 kg.

EXHIBIT 10

Distribution of rated load weight for ELVs in Shenzhen



The volumetric carrying capacity of ELVs relative to ICE vehicles is less straightforward to evaluate. According to equipment manufacturers, the volumetric load carrying capacity of ELVs, both minivans and light trucks, is equivalent to that of ICE vehicles. However, when interviewing fleet owners and managers, opinions differed. Some owners and managers agreed with OEMs that ELVs have the same volumetric carrying capacity as ICE vehicles. Other fleet owners and managers said that, due to space used by batteries and other components specific to ELVs, volumetric capacity is only 70% of average ICE vehicles. The data platform did not have information about usable volume for ELVs, so the research team was not able to answer this question definitively.

Finally, in terms of the types of freight that ELVs can transport, some fleet owners and managers stated that ELVs may have difficulty maintaining stability in turns when carrying higher-density goods (e.g., bottled water, building materials, etc.). However, only a relatively small minority of owners and managers expressed that concern, so its severity may be limited to specific models.

On the other hand, many fleet owners and managers believed that a key shortcoming of ELVs lies in their inability to effectively serve cold-chain applications. Using ELVs in refrigerated goods delivery poses two problems. The first is that keeping refrigerators running requires extra energy, shortening vehicle ranges. The second issue is that both the weight of the refrigeration equipment itself, combined with the weight of extra batteries needed to meet range requirements, exacerbates the existing problem of the lower weight-based carrying capacity of ELVs.

This phenomenon was observable in the data. In 2019 there was a total of 1,044 electric refrigerated vehicles in Shenzhen, including 790 light trucks, 51 minivans, and 203 other models. However, most of these vehicles are idle. The ratio of operation to total days (see the *Background Volume* for further discussion of this metric) of refrigerated electric light trucks in Shenzhen was less than 15%, which is far behind the level both of other ELVs and ICE logistics vehicles.

CONCLUSION

CONCLUSION

Based on the above assessment of the technical quality of ELVs in Shenzhen, the research team drew the following conclusions:

- ELVs are broadly up to the task of urban goods distribution in Shenzhen. However, using ELVs currently comes with some compromises due to shorter range, lower maximum payloads, and, possibly, lower volumetric payloads than ICE vehicles. Furthermore, ELVs underperform in certain applications, such as refrigerated goods distribution, and are viewed with skepticism by some users distributing heavy, dense goods such as beverages and construction materials.

- Ongoing development of battery technology will be necessary to ensure the full replacement of ICE vehicles with ELVs. Currently, observed ranges of ELVs are sufficient for many urban logistics applications in Shenzhen. However, it is clear that increasing vehicle range through improved battery energy density will be necessary for sustained growth of the ELV market. This conclusion is supported by factoring in differences in achieved range versus labeled range, the variance in achieved range, and relatively rapid capacity degradation.

- Issues with battery degradation must be solved in order for ELVs to present a cost proposition that is superior to ICE logistics vehicles. It is common for ELVs, especially light trucks, in Shenzhen to have battery lives that are as short as three to four years. Our analysis of vehicle faults suggests that much of that rapid degradation is due to the use of fast charging, which is a feature of the ELV market in Shenzhen. Based on trends in the charging market, a transition to slow charging is unlikely. Therefore research must be focused on both improving the vehicles' ability to regulate power to the battery to avoid degradation, and also on the development of battery chemistries that are better able to accommodate fast charging than today's batteries.

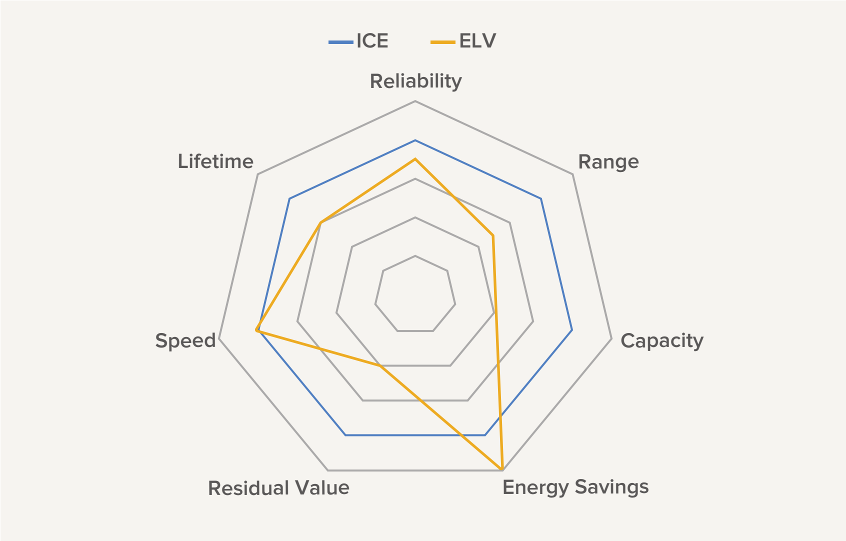
- A universally accepted method for determining the remaining useful life of batteries is critical to both the ELV value proposition as well as enabling business models based on second-life batteries. Currently, there is no accepted methodology to determine how far batteries have degraded. This both hinders fleet owners and managers' ability to exercise warranty claims and reduces the value of ELVs in the second-hand market. The research team suggests that national authorities design a set of standards for making such a determination.

- EV failure rates are lower than ICE vehicles, but certain types of battery-related failures pose safety risks and can cause vehicle downtimes of up to a month. Three aspects of failure most concerned fleets. The first was safety issues associated with overheating batteries and battery fires—specifically battery short-circuits due to lithium dendrite formation accelerated by the use of fast charging. The second was the rate of battery degradation and the impact of battery replacement on both ELV total cost of ownership (TCO) as well as utilization. The third was around the time needed to repair an ELV when a serious maintenance issue occurred. Due to immature supply chains for ELV parts and limited availability of ELV maintenance expertise, serious repairs often took a month or more, imposing high utilization penalties.

In summary, ELVs have reached or exceeded the level of fuel trucks in certain indicators—power output and energy savings (and associated emissions reductions)—but lag ICE vehicles in a number of core indicators—service life, vehicle range, load capacity, and residual value. Exhibit 11 represents the team's assessment of ELVs versus ICE vehicles on those metrics.

EXHIBIT 11

Comprehensive comparison between ELVs and ICE trucks in Shenzhen



In the next stage of ELV promotion in Shenzhen, a focus should be put on expanding the capabilities of ELVs to capture more markets and routes. To do so, industry and national-level policymakers must work together to address issues with batteries that disadvantage ELVs relative to ICE vehicles. Critical areas for improvement include battery degradation, which make ELVs less attractive than ICE vehicles on metrics such as useful life and residual value, as well as battery energy density, which make ELVs less attractive than ICE vehicles on metrics such as range and loading capacity.

At the same time, actions independent of ELV users can also enhance the value proposition of ELVs. In particular, standards to enable the evaluation of residual battery capacity in degraded batteries, as well as the development of second-life battery applications, all hold the potential to increase the residual value of ELVs and improve their overall value proposition to users.

ENDNOTES

ENDNOTES

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2. General Office of the State Council, Tenth Five-Year Plan for National Economic and Social Development, 2001; and General Office of the State Council, Eleventh Five-Year Plan for National Economic and Social Development, 1996.

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11. "A wave of scrapped EV batteries is coming," *Science and Technology Daily*, 2019.

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