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Exploration on Micro-mobility in Urban Transportation

Linze Xie, Mengyu Zhao, Kekaiyan Miao, Qi Lyu

Universiti Malaya, Kuala Lumpur, Malaysia

Keywords: micro-mobility, urban transportation, sustainable development, sharing economy, technological innovation

Abstract: cording to the development of urbanization, micro-mobility has become an innovative solution for short-distance travel, replacing traditional car use gradually. It has also played a vital role in easing traffic congestion and reducing carbon emissions. By analyzing the current situation of micro-mobility in Malaysia, this paper discusses the technical support, market demand, policies, regulations, and social challenges facing its development. The research shows that the main advantages of micro-travel include: Improving urban commuting efficiency and easing traffic congestion; Promoting environmental sustainability and reducing carbon emissions by reducing the use of fuel vehicles; Significant cost-effectiveness, providing users with a more economical short-distance journey; Health benefits include promoting physical fitness through cycling. In addition, innovations in micro-mobility technologies, such as the Internet of Things and the application of big data, are also driving the development of smart cities. However, micromobility still needs to overcome many challenges in its rollout, including inadequate infrastructure (such as dedicated lanes and parking facilities), weak safety awareness among users, inadequate regulations, social equity issues, and restrictions on use due to climate conditions. Through case studies, such as the successful experience of the public bicycle system in Hangzhou, China, and the failure lessons of the excessive use of shared bicycles in Shenzhen, the paper further validates the key role of policy support and management mechanisms in the development of micro-mobility. The paper suggests that through policy optimization, technological innovation, infrastructure construction, and social publicity, the user acceptance and safety of micro-travel can be effectively improved. The development of micro-mobility can not only improve the urban transportation system but also play an important role in promoting social equity, economic development, and environmental protection.

1. Introduction

1.1 Research Background

Nowadays, shared micro-mobility has become a trend in cities as an alternative to conventional automotive vehicles, especially for short-distance travel. It also plays an important role in the

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reduction of the number of automotive vehicles which results in a decrease of air pollution and traffic congestion. Micro-mobility is increasingly recognized as a promising mode of urban transport, particularly for its potential to reduce private vehicle use for short-distance travel.

1.2 Research Issues and Objectives

Based on the analysis of the situation and status quo of micro-mobility in Kuala Lumpur, Malaysia, the paper tries to find the reasons why micro-mobility is not well used in Kuala Lumpur. In the case of such a serious traffic congestion problem, how to advocate people's micro-mobility, how the government, society and individuals should interact to make the micro-mobility mode in Kuala Lumpur more popular, more beneficial to the people, safer and more effective.

1.3 Significance of research

Through the discussion, effective ways can be found to solve the problem of safety and popularity of micro-mobility in Kuala Lumpur. To solve the problem of traffic congestion in Kuala Lumpur, reducing the dependence on fossil fuels helps to reduce carbon emissions and air pollution, and also provides residents with diversified short-distance travel methods, which can reduce personal travel costs and promote the application and development of emerging technologies.

2. Definition and types of micro-mobility

2.1Definition

Micro-mobility refers to a series of mobility modes using small and light vehicles, mainly including bicycles, electric bicycles, electric motorcycles and electric scooters. These vehicles usually weigh no more than 350kg and are designed for speeds of no more than 45km/h. If equipped with power assistance, they will automatically slow down or cut off the power supply. Micro mobility is a flexible and convenient way to travel, suitable for short trips and city commuting. It does not need a long time of careful planning and a lot of packing, and can be set off at any time.

2.2Types and characteristic

(1)Bicycle: Traditional bicycle, relying on human power to ride.

(2)Electric bicycle: through electric assistance riding, suitable for short and medium distance travel.

(3)Electric motorcycle: a more powerful electric vehicle suitable for longer commutes.

(4)Electric scooter: light, flexible, suitable for short trips in the city and the last kilometer problem solving.

3. Advantages of micro-mobility

3.1 Reducing Urban Congestion

As urbanization increases, the high-density use of traditional vehicles leads to urban congestion and inefficient traffic flow. Micro-mobility tools, being lightweight, flexible, and compact, help alleviate short-distance traffic issues, particularly in city centers. For example, in Kuala Lumpur near the KLCC Twin Towers, e-scooters allow people to navigate short distances quickly and conveniently, avoiding congested areas and reaching shopping malls efficiently.

3.2 Environmental Sustainability

In Malaysia, affordable fuel prices have led to many households owning multiple cars. This reliance on private vehicles results in increased carbon emissions and pollution. A gradual shift towards micro-mobility can significantly reduce emissions, promoting environmental sustainability. Solving the "Last Mile" Problem: Micro-mobility tools are ideal for bridging the gap between public transit stations and final destinations. They provide seamless connectivity and effectively complement traditional public transport systems. For instance, traveling from Southbank Residence to the Twin Towers in Kuala Lumpur may involve a bus, a metro ride, and a 170-meter walk. E-scooters available at metro exits make this final segment quicker and more convenient, which is especially appealing in Kuala Lumpur's hot climate.

3.4 Cost-Effectiveness

The rental cost of micro-mobility tools is relatively low, sparing users from purchasing vehicles and paying for insurance. Compared to taxis or private cars, micro-mobility is a more economical option for short daily commutes.

3.5 Health Benefits

Some micro-mobility options, such as bicycles, encourage physical activity, promoting better physical fitness and health. For city dwellers with sedentary lifestyles, biking and other forms of micro-mobility offer a beneficial exercise choice.

3.6 Innovation in Technology

The rapid growth of the micro-mobility sector drives the application of IoT, shared economy models, and big data, contributing valuable data and technological support for smart city initiatives. This growth has also sparked new business models and market opportunities.

4. Technical Support for Micro-mobility in Malaysia

As Malaysia seeks sustainable urban mobility solutions, particularly in its major cities, the technical support behind micro-mobility, including device technology, system technology, and safety advancements, plays a vital role in enabling its growth.

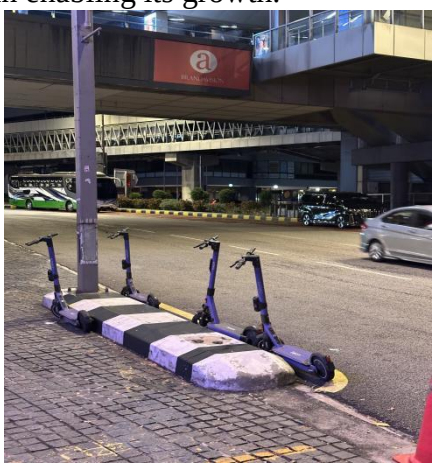

Fig 1Sharing E-scooter in Kuala Lumpur

4.1 Device Technology for Micro-mobility

The success of micro-mobility in Malaysia, especially in cities like Kuala Lumpur and Penang, heavily relies on device technology. Key factors such as battery life and charging infrastructure are crucial, as they directly affect the efficiency of electric scooters and bikes. Malaysia's high humidity and frequent rainfall create challenges for micro-mobility providers, requiring devices to be durable and weather-resistant. Lightweight, foldable designs and waterproofing features are vital for adapting to Malaysia's climate and densely populated urban areas. Additionally, GPS tracking and app-based real-time location tracking allow operators and users to monitor and manage devices more effectively, enhancing both operational efficiency and user experience.

4.2 System Technology for Micro-mobility

In Malaysia, micro-mobility technology has advanced through collaborations with local platforms and app developers. Leading platforms like Beam and Tryke have developed intuitive apps that streamline real-time rentals, secure payments, and customer support services. Effective fleet management on the back end is essential, with data analytics allowing operators to anticipate peak times and allocate vehicles strategically to meet demand. Leveraging big data in micro-mobility systems enables adaptive responses to shifts in real-time demand, ensuring optimal fleet usage and enhanced user satisfaction. This strategy is particularly valuable in Kuala Lumpur, where high traffic congestion aligns with peak demand periods, making micro-mobility a promising choice for last-mile connectivity.

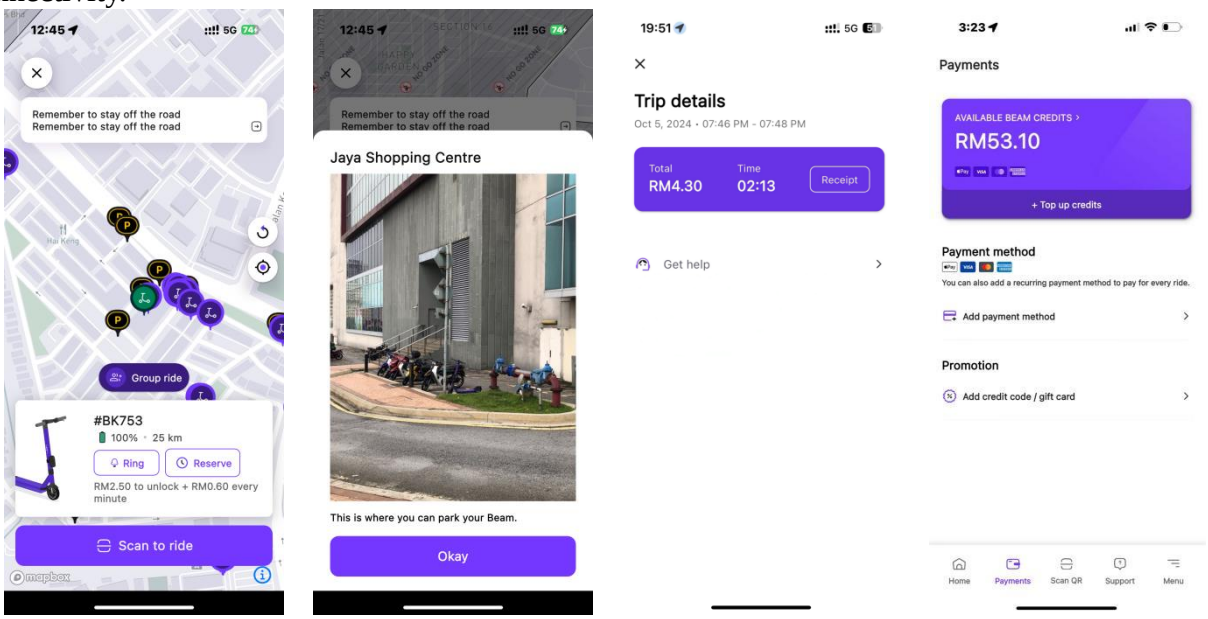

Fig 2 The Cost of the Sharing E-scooter

4.3 Safety Technology

As micro-mobility gains traction in Malaysia, safety technology has become essential. Features like speed limiters, smart braking systems, and anti-collision sensors have been implemented to reduce accident risks. Additionally, both government and private providers are using geo-fencing technology to restrict device usage in high-risk or unauthorized areas. Malaysia's Ministry of

Transport is also working on smart infrastructure projects, including adaptive traffic lights and digital signage, aimed at improving safety for micro-mobility users in busy urban zones.

5. Market Status and Demand Analysis of Micro-mobility in Malaysia

The micro-mobility market in Malaysia has grown significantly in recent years, influenced by urbanization and increased awareness of sustainable transport options.

5.1 Overview of the Micro-mobility Market in Malaysia

Malaysia's micro-mobility market has been on a steady growth trajectory, especially in densely populated areas like Kuala Lumpur, Penang, and Johor Bahru, where there is strong demand for short-distance travel options. Companies such as Beam, Tryke, and Neuron have expanded their operations to meet the commuting needs of urban populations. Data from 2022 suggests that this market will continue to grow, driven by both public and private investments aimed at promoting sustainable urban mobility. Government initiatives, including the Low Carbon Cities Framework (LCCF), further highlight Malaysia's commitment to reducing emissions, positioning micro-mobility as an essential element in achieving this objective.

5.2 User Demand Analysis

Analysis of user demand shows that micro-mobility in Malaysia fulfills various needs, including last-mile connectivity, short-distance commutes, and recreational activities. A large portion of the user base consists of young urban dwellers, tourists, and students. The primary factors driving their choice are cost savings, convenience, and environmental advantages. With traffic congestion persisting in Kuala Lumpur and other major cities, many commuters see micro-mobility as a flexible option to avoid traffic and reach their destinations faster. Additionally, the focus on environmental sustainability is increasingly influential, as users become more conscious of reducing their carbon footprint.

5.3 Competitive Analysis

In the Malaysian transport ecosystem, micro-mobility faces competition from both public transportation and private vehicles. While micro-mobility provides a flexible and convenient solution for short trips, it cannot yet fully compete with the reach and reliability of the public transport system. However, micro-mobility complements public transportation by filling the gap for last-mile travel, making it an appealing option for urban dwellers who want to avoid parking fees and congestion. Additionally, as the government expands dedicated cycling lanes and pedestrian-friendly pathways, micro-mobility's role as a supplementary transport option is likely to grow, especially in high-density urban areas.

6. Policy and Regulatory Impacts on Micro-mobility in Malaysia

Government policies and regulations play a crucial role in shaping the growth and sustainability of the micro-mobility sector in Malaysia.

6.1 Comparison of Global Policies and Malaysia's Current Policy

Malaysia remains in the early stages of regulating micro-mobility compared to Western countries. While the government has established some foundational guidelines, such as licensing requirements

and parking restrictions, the regulatory framework is still evolving. In contrast, cities across Europe and North America have implemented more advanced micro-mobility policies that encourage infrastructure development and prioritize user safety. Nonetheless, Malaysia has made progress by designating specific parking zones in Kuala Lumpur and enforcing speed limits to enhance public safety. These measures highlight Malaysia's cautious, step-by-step approach to incorporating micro-mobility into its urban transport system.

The Transport Minister Datuk Seri Dr Wee Ka Siong stressed that the government had never banned the use of micromobility vehicles in Malaysia, adding that the vehicles should only be operated in a safe and controlled environment.

6.2 Impact of Policies on Micro-mobility

The Malaysian government's dual approach to micro-mobility policies has both promoted and restricted its growth. On the one hand, policies like licensing requirements and parking regulations have increased operational costs for micro-mobility providers. On the other hand, initiatives supporting low-carbon city developments and sustainable transport indicate a shift towards fostering a more micro-mobility-friendly environment. The support from local governments, such as the installation of dedicated lanes in certain urban areas, is gradually easing the integration of micro-mobility into the broader urban transport system. However, further policy adjustments are needed to maximize its potential as a sustainable transport option.

6.3 Recommendations for Policy and Regulatory Optimization

To ensure the sustainable development of micro-mobility in Malaysia, several policy optimizations are recommended. First, enhancing safety standards by mandating regular equipment checks and implementing comprehensive insurance requirements for operators could reduce accidents and build public trust. Additionally, expanding parking zones and providing designated paths for micro-mobility vehicles could alleviate congestion on sidewalks and reduce conflicts with pedestrians. Finally, introducing tax incentives or subsidies could encourage private companies to invest in micro-mobility infrastructure, while campaigns promoting micro-mobility as a green and practical choice could boost user adoption. These improvements would contribute to a more orderly and sustainable micro-mobility environment, aligning with Malaysia's long-term urban transport goals.

7. Social impacts and challenges of micro-mobility

7.1 Inadequate Infrastructure:

The current primary problem of micro-mobility (e.g., shared bikes, e-scooters, e-bikes, etc.) in Malaysia is the lack of well-developed infrastructural support, which poses significant social impacts and challenges, especially in traffic-intensive areas such as Kuala Lumpur:

7.1.1 Poorly planned roads and lanes

Roads and parking design mainly consider the needs of motor vehicles and lack of travel lanes and parking areas dedicated to serving micro-mobility, which also leads to the fact that micro-mobility tools such as scooters and bicycles are forced to travel on sidewalks and motorized vehicles, which increases the risk rate of accidents to a certain extent [13]. Inadequate infrastructure poses a particular barrier to micro-mobility, especially in large cities such as Kuala Lumpur, where highways and

arterial roads are the main routes for daily travel, which are heavily trafficked and unsuitable for micro-mobility vehicles.

7.1.2 Inadequate parking facilities

Due to the lack of dedicated parking areas for micro-mobility, many shared bicycles and electric scooters are parked on sidewalks, bus stops, public plazas, or building entrances, which affects the appearance of the city and hinders the movement of other citizens, especially the elderly and the disabled.

Fig 3 The Parking of the Sharing E-scooter

7.1.3 Inadequate traffic safety facilities

The road infrastructure in Malaysia does not adequately consider the safety needs of micro travelers and lacks facilities such as barricades and guardrails to protect micro travelers. At the same time, many road sections lack warning signs and speed alerts for micro-trippers, resulting in higher safety risks for micro-trippers traveling at intersections and complex road sections, which increases the incidence of traffic accidents. In addition, the lack of nighttime lighting facilities also exacerbates the danger of nighttime riding to a certain extent.

7.1.4 Lack of charging and maintenance facilities

The mobility tools such as electric scooters and electric vehicles in micro mobility cannot be separated from battery power, thus requiring the construction of charging facilities in public places. However, in the current situation in Malaysia, the construction of charging facilities for micro-mobility is lagging behind, thus making it difficult for micro-mobility users to charge easily. In addition, micro mobility tools require regular maintenance, but Malaysia currently lacks regular maintenance facilities, resulting in mobility tools are prone to malfunction, increasing the risk of users. The lack of the above two facilities has somewhat limited the popularity of micro mobility.

7.1.5 Summary of this chapter

In Malaysia, the lack of infrastructure can limit the development potential of micro-mobility and bring about safety risks, management difficulties, and disorganization of public space in the society. In order to improve this situation, the government and enterprises need to invest in improving infrastructure, including the installation of additional micro-mobility lanes and parking areas, and the improvement of traffic signs and safety facilities to ensure the safety and convenience of

micro-mobility so that it can better serve the urban transportation system.

7.2 Micro-mobility and Social Equity:

While promoting travel convenience, micro-mobility also poses challenges for social equity. Despite the rapid growth of micro-mobility, there are significant differences in access and experience among different social groups.

7.2.1 Unequal distribution of resources

The deployment of micro-mobility tools and the construction of infrastructure are mainly concentrated in urban centers, business districts and transportation hubs, and other areas with high pedestrian flow and high income, while in suburban areas and low-income communities, the deployment is less and the infrastructure is more backward. This uneven distribution of resources not only results in residents of suburban and low-income communities having difficulty in easily accessing micro-mobility services and limited travel options, but also increases travel risks to a certain extent. For example, the lack of safe lanes and parking facilities leads to many safety hazards for residents in these areas when using micro-mobility.

7.2.2 Differences in affordability and cost of use

The cost of using micro-mobility affects different income groups differently. For high-income groups, this mode of travel is seen as an affordable short-distance travel option, but for low-income groups, the cost of using micro-mobility for a long period of time may become a financial burden for them, which limits their use of this type of travel mode to some extent. In addition, some micro-mobility platforms adjust prices or charge surcharges during peak periods, which not only increases the economic burden of low-income people, but also makes micro-mobility less popular among low-income people, which affects the fairness of travel modes to a certain extent.

7.2.3 Digital divide

Micro-mobility services usually rely on smartphone apps for registration, rental and payment operations. However, this may be difficult for low-income people, some elderly people and residents in rural areas, who may lack smartphone-related digital operation skills, making it difficult for them to use these services. At the same time, uneven network coverage in some rural areas makes the ease of traveling in micro lines still hard to reach, further exacerbating social equity issues.

7.2.4 Summary of this chapter

In order to achieve more equitable micro-mobility services in Malaysia, the government and businesses need to consider expanding the scope of services, strengthening the infrastructure in low-income communities, reducing the economic burden, bridging the digital divide, and ensuring the safety of micro-mobility tools so that micro-mobility becomes an accessible mode of travel for any social group and promotes equity in society as a whole.

7.3 User safety issues

In Malaysia, user safety issues arising from micro-mobility have raised social concerns. These safety issues are mainly related to factors such as inadequate infrastructure, poor traffic rules, users' safety awareness and design flaws of the micro-mobility tools themselves.

7.3.1 Safety Problems Brought about by Inadequate Infrastructure

Due to the lack of dedicated lanes for micro-mobility, micro-mobility need to mix with motor vehicles, especially in busy traffic sections, which increases the risk of accidents; the lack of lighting facilities at night, as well as the lack of signage and protective facilities, all increase the dangers of micro-mobility at night to a certain extent, so that the user's safety is at risk; the daily maintenance and overhaul of micro-mobility equipment construction is deficient, and if it is not regularly overhauled, this could the daily maintenance and overhaul construction of micro-mobility equipment is insufficient, if not regularly overhauled, it may lead to the existence of potential obstacles in the important parts of micro-mobility tools, which will directly affect the safety of users when traveling and lead to accidents.

7.3.2 Weak user safety awareness

Some micro-mobility users lack basic knowledge and awareness of safe use, such as not wearing helmets, not obeying traffic signals, not paying attention to pedestrians, etc., and these behaviors increase the risk of accidents. In addition, young people and teenage groups have insufficient knowledge of the risks of micro-mobility, and sometimes, in order to seek excitement, they may use micro-mobility tools as recreational equipment for drag racing, leading to the emergence of speeding, sudden lane changes, and other irregularities, which not only puts themselves at risk, but also threatens the safety of other road users.

7.3.3 Inadequate traffic regulations

Traffic rules and regulations for micro mobility in Malaysia are not yet sound, resulting in a lack of standardized behavioral guidance for micro mobility users on the road, such as speed limits, driving zones, etc.. The inadequacy of regulations makes some users need to drive in complex roadways or high-traffic areas, which increases the chance of accidents. At the same time, some of the micro mobility tools are insufficient in terms of driving technology and safety training, and there are great safety risks for users to use micro mobility tools without sufficient safety knowledge.

7.3.4 Summary of this chapter

In Malaysia, the user safety of micro mobility is a prominent issue, mainly due to the lack of infrastructure, weak user safety awareness, and poor traffic rules. In order to enhance the safety of micro-mobility, the government and enterprises need to take comprehensive measures to ensure the safety of micro-mobility users and other road users, including the installation of additional dedicated lanes, upgrading the quality of equipment and maintenance standards, improving traffic regulations, and strengthening safety awareness and user training. At the same time, law enforcement and supervision should be strengthened to promote greater standardization of micro-trips.

7.4 User Acceptance

User acceptance of micro mobility in Malaysia is influenced by a number of factors. These influencing factors include infrastructure, social perceptions, safety, and cost, making micro-mobility's acceptance vary among different groups.

7.4.1 Safety issues limit user acceptance

Due to the lack of well-established safety facilities and clear regulations, micro-mobility users face

high safety risks in Malaysia, especially the risk of collision when mixing with motorized vehicles. In addition, the equipment of some micro mobility tools is not adequately maintained, and malfunctioning of brakes, lights, and other features are common. The safety issue has made some potential users apprehensive about micro-mobility tools, affecting their acceptance of this mode of travel.

7.4.2 Climatic constraints

Malaysia's tropical climate and frequent rainfall have an impact on the acceptability of micro-mobility. In a hot environment, using shared bicycles or electric scooters for a long period of time can cause people to feel unwell, which not only affects the sense of user experience, but also affects the acceptance of users to a certain extent. In addition, when Malaysia is in the rainy season, frequent rains lead to slippery roads and reduced safety of micro-mobility tools, which makes users reluctant to use such modes of travel when the weather is bad. Therefore, the impact of climatic factors can limit the usage of micro-mobility and also reduce its acceptance in daily life.

7.4.3 Influence of Social Perception

Micro-mobility is still new in Malaysia, and some users have limited knowledge and understanding of it, especially the elderly, who are still accustomed to using private cars or public transportation to travel and are not willing to accept the new micro-mobility tools. It can be seen that the influence of social perception on the acceptance of micro mobility is significant, and the acceptance of new mobility modes is low in communities with strong traditional attitudes, which makes it difficult for micro mobility tools to be popularized among all age groups and communities.

7.4.4 The impact of cost factors on user acceptance

The cost factor plays an important role in people's travel choice of transportation mode. When the deposit and prepayment pricing of some micro-mobility rental platforms exceeds the user's travel budget and creates a certain economic burden, it will affect the user utilization rate to a certain extent and become a major obstacle to user acceptance.

7.4.5 Summary of this chapter

User acceptance of micro-mobility in Malaysia faces multiple challenges, including safety issues, social perceptions, climate constraints, and cost burden. To enhance user acceptance, it is necessary for the government and enterprises to improve the infrastructure of micro-mobility, enhance safety, establish clear regulations, and strengthen publicity and promotion at the social level to help more people understand and accept this emerging mode of mobility.

7.5 Regulatory issues:

In Malaysia, while micro-mobility provides a flexible and convenient solution for urban transportation, it also poses many regulatory challenges. These challenges mainly include the lack of laws and regulations, unclear departmental responsibilities, traffic safety hazards and urban space management, which have far-reaching impacts on urban management and social order.

7.5.1 Lack of laws and regulations

Malaysia still lacks laws and regulations related to micro mobility devices, such as driving zones,

speed limits, and safety standards. These legal gaps make it impossible for operators and users to standardize the code of conduct in practice, which can easily lead to violations and create greater safety risks for micro-mobility.

7.5.2 Uncertainty in the division of departmental responsibilities

The management of micro-mobility involves a number of departments, but in the current situation in Malaysia, the division of responsibilities between departments is not clear and there is a lack of effective coordination mechanisms. These problems may lead to the shifting of responsibilities between departments in the event of accidents or indiscriminate parking of micro-mobility, making the regulation ineffective and to some extent increasing the difficulty of management.

7.5.3 Public space management challenges

Due to the lack of unified parking management norms and facilities, the problem of haphazard parking of shared bicycles and electric scooters is more prevalent in urban areas in Malaysia. The indiscriminate parking of miniature mobility tools not only occupies sidewalks and public space, but also affects the right of passage of other citizens and the cityscape. The government needs to strengthen the management of public space by designating dedicated parking areas or introducing smart parking systems to solve such problems [14].

Fig 4 Misplaced Sharing E-scooter

7.5.4 Data security and privacy issues

Micro-mobility relay on smartphone software programs for registration and payment, as well as synchronized recording of user travel data and geographic location, so user information security is very important, but there is still a lack of effective measures to protect user data privacy in Malaysia.

Some operators may utilize user data information to make profit, which may bring some security risks to users, therefore, the Malaysian government needs to strengthen the protection of user data privacy.

7.5.5 Summary of this chapter

In Malaysia, shared micro mobility faces many management challenges in terms of regulations, allocation of government responsibilities, vehicle parking and data security. To cope with these issues, the government and enterprises need to work together, with a clear division of labor among government departments, improving relevant regulations and standards, building well-regulated and adequate parking facilities, and strengthening efforts to regulate operators' user data and protect data privacy, so as to promote the sustainable development of shared micro-mobility.

7.6 Malaysia scooter user survey results

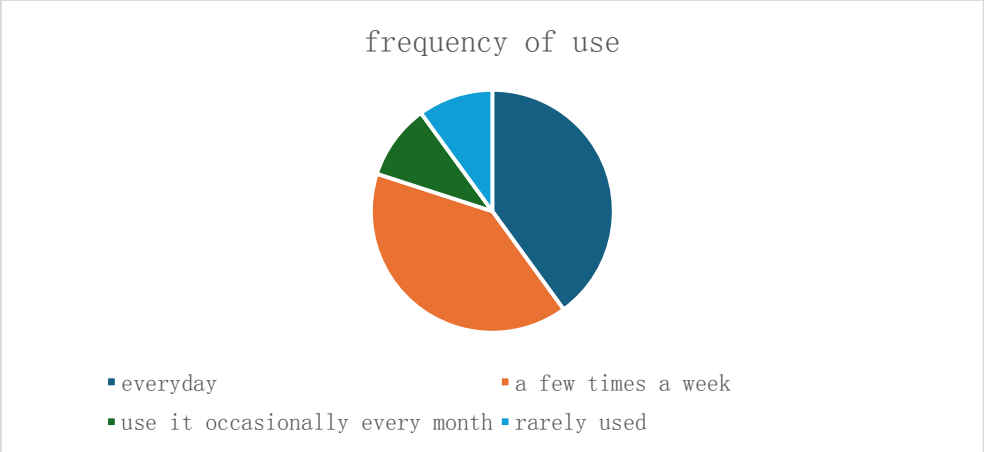

Fig 5. How often do you use your scooter?

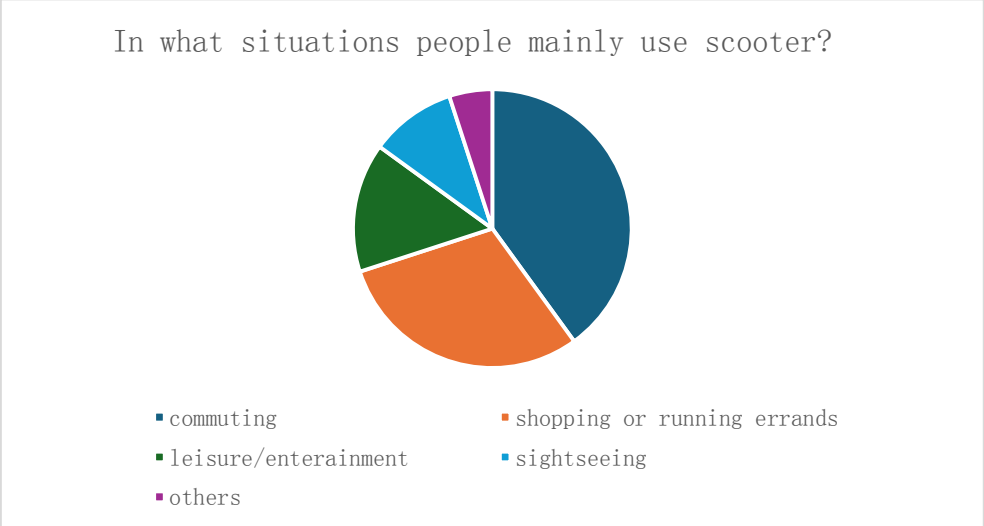

Fig 6. In what situations do you mainly use scooter?

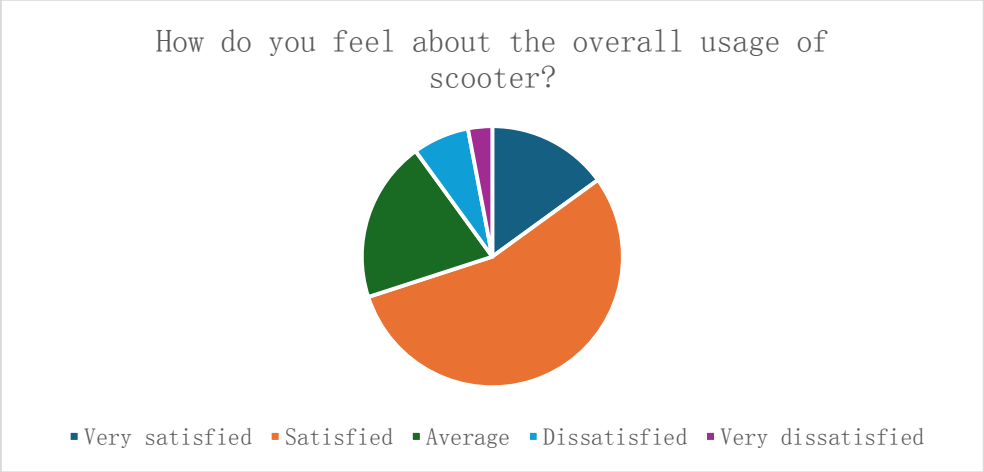

Fig7. How do you feel about the overall usage of scooter?

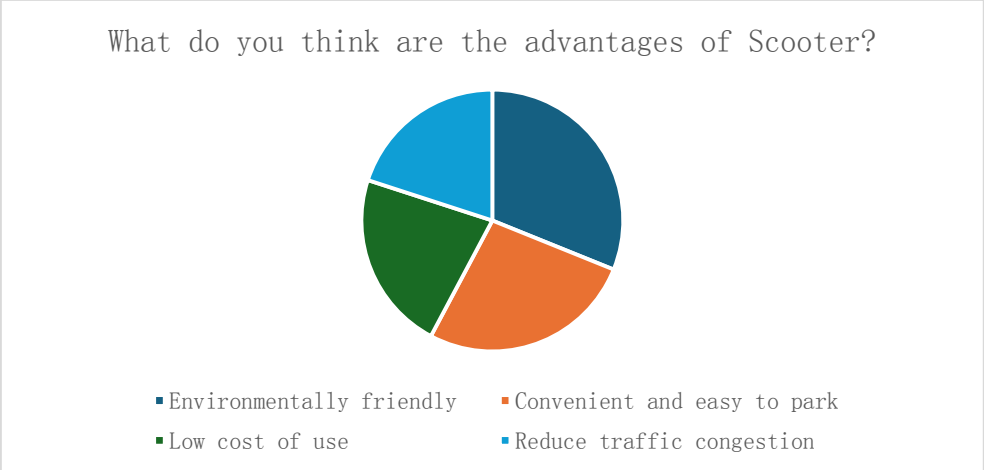

Fig 8.What do you think are the advantages of Scooter? (Multiple choice)

Fig 9. Do you think the current price of scooter is reasonable?

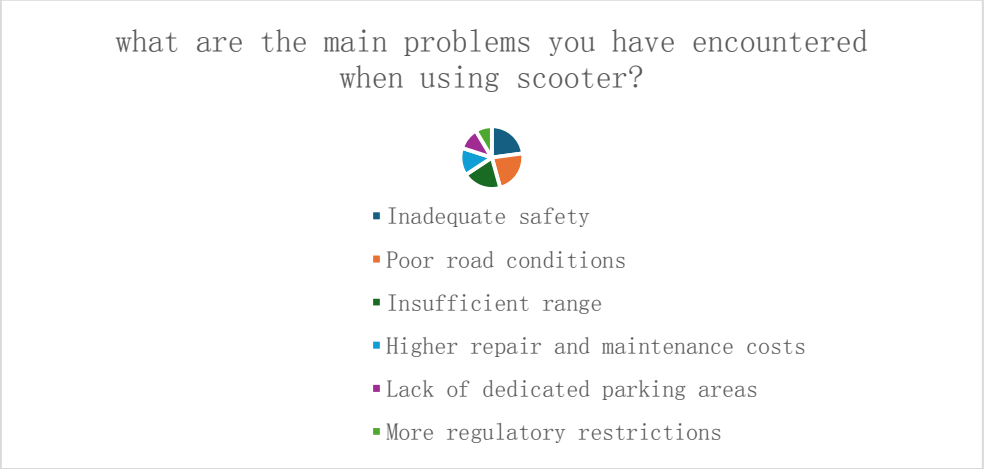

Fig 10. What are the main problems you have encountered when using scooter? (Multiple answers allowed)

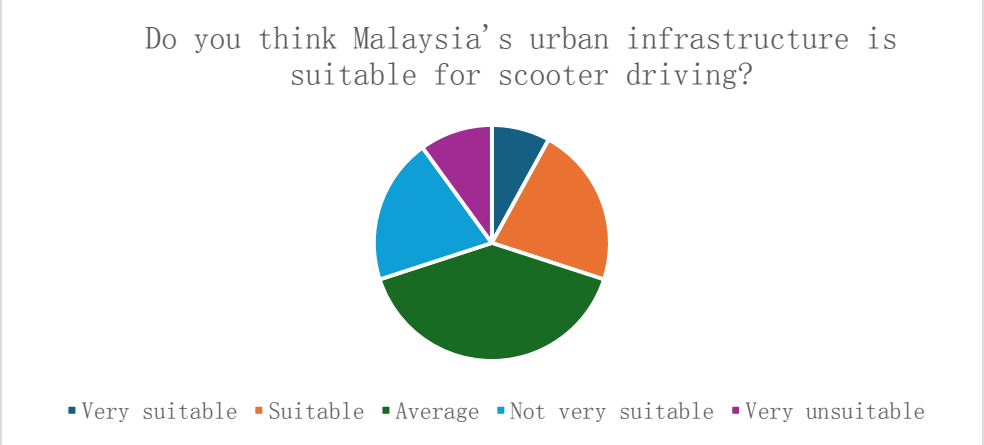

Fig 11. Do you think Malaysia's urban infrastructure is suitable for scooter driving?

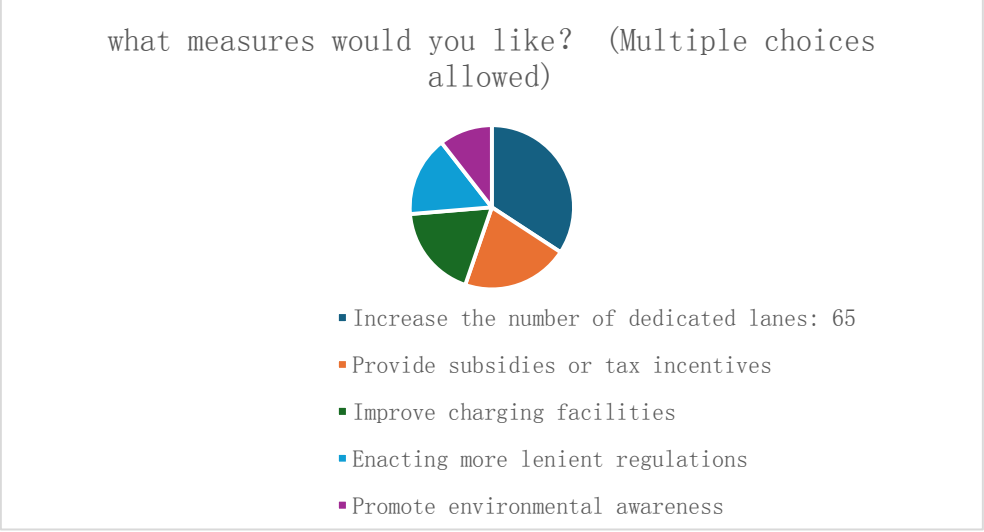

Fig 12. What measures would you like the government or relevant departments to take to support the development of scooter? (Multiple choices allowed)

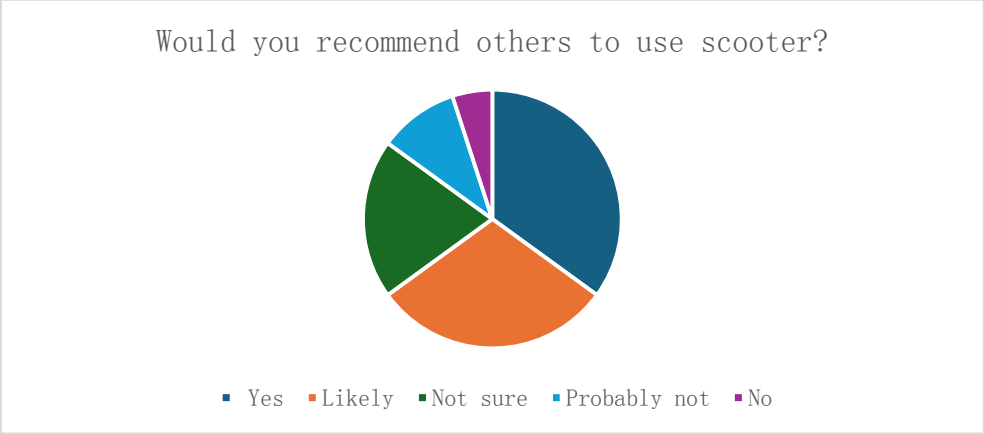

Fig 13.Would you recommend others to use scooter?

The results of this survey show that scooter users in Malaysia generally recognize the convenience and environmental friendliness of scooters, and most are willing to continue to use and recommend scooters; however, there are still concerns about safety, infrastructure adaptability, and affordability. Most users would like to see more infrastructure improvements, such as dedicated lanes and charging facilities, and expect the government to provide more support for scooter travel.

8. Case studies

8.1 Successful Case Study -Public Bicycle System in Hangzhou, China

The public bicycle system in Hangzhou, China is one of the earliest and most successful public bicycle programs in the world. The system was launched in 2008 and is now the mainstream choice for short distance travel for Hangzhou citizens.

8.1.1 Reasons for success:

(1) Extensive Station Layout: Hangzhou has a large number of public bicycle stations throughout the city, covering all neighborhoods, large commercial buildings and supermarkets. The government is even planning to set up bicycle lanes on viaducts to ensure that citizens can find a rental spot within 500 meters, which greatly improves ease of use.

(2) Low cost and government subsidies: The system implements extremely low rental fees, even free of charge for short-distance use, which attracts a large number of public users with such a low-cost policy. In addition, the government's strong support and financial investment is also the key to its success.

(3) Government-led operation model: Unlike the private operation models in Europe and the United States, Hangzhou's public bicycle system is government-led and managed in a unified manner, which reduces the complexity of management and operation and ensures the efficient operation of the system.

8.1.2 Successful model:

The successful model of Hangzhou's public bicycle system lies in the dominant position of the government, which realizes low cost and convenient services through strong subsidies and effective management, making public bicycles an important supplementary tool for daily travel.

8.2 Lessons from Failure Cases-Excessive Bicycle Sharing in Shenzhen, China

Bike-sharing has become widely popular in China, but it has also faced a large number of problems in major cities such as Shenzhen, especially the problem of over-investment. In the early days, many bike-sharing companies placed too many bikes in Shenzhen, leading to the phenomenon of "bike siege" in the city, and even the emergence of a large number of "bike graveyards".

8.2.1 Reasons for failure:

(1) Excessive competition in the market: many companies competed excessively and put in more bicycles than the market demand, resulting in a large number of bicycles lying idle.

(2) Lack of management and coordination: the government lacks effective supervision over the number of bicycles placed, resulting in a large number of bicycles occupying public space in the city, affecting traffic and cityscape.

(3) Insufficient maintenance by enterprises: due to high operating costs, some companies failed to recover and maintain faulty bicycles in a timely manner, resulting in a large number of damaged and piled-up bicycles.

8.2.2 Lessons learned:

(1)The government needs to set clear placement standards and quotas in the early stage of micro-mobility development to avoid excessive competition in the market.

(2)Enterprises need to take the responsibility of equipment maintenance to avoid the waste of public resources and damage to the cityscape.

8.3 Current status of micro-mobility development in a typical city- Paris, France

Paris is one of the first cities in Europe to promote bike sharing, and its bike sharing system, Velib, has become a global benchmark for public bike sharing. In addition, Paris is constantly innovating travel modes, actively introducing micro-mobility tools such as shared electric scooters, and diversifying and eco-friendly transportation through cooperation with private companies.

8.3.1 Development status:

(1) Wide coverage of the bike-sharing system: the Velib bike-sharing system in Paris has covered the city. This system not only provides a variety of models for the public to choose, but also sets up parking spots in metro stations, bus stops and other areas, making it convenient for the public to travel and transfer between public transportation.

(2) Strict regulation: The Paris government has invested a lot of effort in regulation, not only implementing a strict license management system for micro mobility companies, but also requiring operators to meet environmental and safety standards. In addition, it has made clear and detailed regulations on the driving speed and parking norms of scooters, which to a certain extent ensures the safety of pedestrians and users.

(3) Advocating environmental protection: Paris has a clear environmental orientation in promoting micro-transportation. The government actively advocates low-carbon travel, encourages citizens to use shared bicycles, shared skateboards and other green travel modes, and regards micro-mobility as one of the effective measures to reduce carbon emissions in the city.

Nowadays, micro-mobility has become a convenient choice for Parisian citizens to travel in their daily life, and is also a symbol of environmental protection life in this city.

9. Future development trends and suggestions

9.1 Technology Trends

As various countries attach great importance to sustainable development, micro-mobility technology is developing in a more environmentally friendly and intelligent direction. Concerns about battery cost, service life, cruising range, and number of charges have long been accused of hindering the promotion of all-electric vehicles, including micro-vehicles. However, rapidly developing battery technology is gradually dispelling these concerns. The cost of lithium-ion batteries is expected to drop by 6.5% annually over the next decade, thus reducing the price of electric vehicles accordingly. Due to the development of new battery technologies, especially the emergence of solid-state batteries and solar cells, traditional lead-acid batteries and gasoline power systems are gradually replacing them. Solid-state batteries have longer endurance and longer service life. The development of solar cells enables these vehicles to self-charge in sunny hours and areas, thus further reducing the dependence on traditional charging methods.

Furthermore, a new battery based on military and industrial technologies is expected to enable safer, faster, and more sustainable battery charging in urban environments. These lithium titanate (LTO) batteries are typically used in smaller or larger devices, such as cell phones or cars, and their unique voltage distribution makes them unsuitable for micro-traffic. However, hardware and software breakthroughs in recent years have helped overcome problems related to LTO by using sensors to automatically regulate voltage and significantly improve integration.

The performance of LTO now surpasses that of traditional lithium-ion batteries in a series of micro-transportation travel indicators. The ultra-sensitive electrode surface area of the LTO means that the battery can be fully charged in less than 20 minutes and can withstand more charging cycles before its life expires.

Free of nickel, manganese, aluminum, and cobalt oxide, LTO batteries also reduce the risk of fire associated with early rechargeable batteries. Honda's EV-neo electric car is already using this technology.

Since micro-vehicles are lighter than cars and do not need to have such a large cruising range, some companies are experimenting with sodium-ion batteries for electric bicycles and scooters. This battery is not only cheaper and reduces unit cost, but also the materials used to produce it are easier to obtain.

In China, many cities have begun to promote shared electric motorcycles and shared bicycles, and the government encourages citizens to use these clean energy vehicles through subsidies and policy support. For example, small cities in China have launched shared electric vehicles, and shared bicycles are more promoted in big cities because traffic is more complicated. However, both shared electric vehicles and shared bicycles reduce carbon emissions in cities and effectively solve the "last mile" problem of travel.

Micro-mobility can also play a good role in intelligent transportation systems. The advantage of

micro-mobility is not only the versatility and flexibility of different types of vehicles. When vehicles are integrated into transportation service platforms, micro-mobility technology can show real charm: people can rent and use vehicles on demand, and enjoy shared transportation based on owning private vehicles. This service platform, which integrates various forms of transportation into a single service project in an intelligent way, is the so-called "Transportation as a Service (MaaS)".

The concept of MaaS and related apps promotes the development of sustainable transportation, improves the intelligence level of urban transportation, and responds to people's growing demand for seamless, green, and personalized transportation, including better connectivity to public transportation.

9.2 Market Trends

The micro-mobility market is expanding rapidly, especially in countries and regions with accelerated urbanization. Forecasts indicate that the global micro-transportation market is expected to reach USD 214.57 billion by 2030, up from USD 44.12 billion in 2020. It does not take much stimulus for consumers to switch their modes of travel to micro-transportation. For example, global e-bike sales soared 240% during the COVID-19 pandemic.

A survey of global business consultants McKinsey & Company shows that about 70% of office workers worldwide would consider using micro-transportation for their daily commute. This suggests in McKinsey analysis that "an increasing number of office workers may be leaning towards smaller, more environmentally friendly modes of transport".

The above statistics illustrate the situation of one. Globally, 40% of people said that bicycles (including e-bikes) would be their preferred micro-transportation commuting option, followed by e-motorcycles (16%) and e-scooters (12%). Less than a third of respondents (31%) did not include micro-transportation as their primary commuting option. According to these data, the future transportation market will tend to be miniaturized, green, and convenient. Among them, shared micro-transportation accounts for a large part of the micro-transportation market.

At present, China's shared bicycle and electric bicycle service market has matured, and shared micro-transportation has attracted a large number of young users. Take Beijing and Shanghai as examples. Bike-sharing services in these cities have become an important choice for daily travel, and users can easily find and rent these transportation facilities through mobile apps.

In Malaysia, the demand for micro-mobility is on the rise as urban traffic pressure increases. Traffic congestion in big cities such as Kuala Lumpur has become increasingly serious, and governments and enterprises have begun to pay attention to the promotion of shared electric scooters. Through the integration with the local transportation system, users can find shared electric scooters near the subway station, which is convenient for them to complete the last mile of travel. This mode not only improves travel efficiency but also provides users with more environmentally friendly travel options.

The market trend is also reflected in consumers' preference for environmentally friendly travel. More and more users are aware of the environmental impact of traditional fuel-fired vehicles and are beginning to choose electric vehicles. Enterprises are also actively responding to this trend and launching more environmentally friendly micro-mobility products to meet market demand.

9.3 Policy support

To promote the development of micro-mobility, the government and relevant departments need to provide specific policy and operational suggestions. First, governments can encourage companies to invest in shared tram projects through subsidies and tax incentives. For example, some cities in China have implemented a purchase subsidy policy for electric vehicles, which has reduced the use cost of consumers and promoted the popularization of electric vehicles.

Secondly, shared trams can also be combined with mobile payment software to improve user convenience. Users do not need to download the APP for sharing trams separately but can rent cars and pay directly through commonly used payment platforms (such as TNG and Grab Pay). This integration not only improves the user experience but also attracts more users to participate in the use of shared trams.

In addition, the government should strengthen the supervision of micro-mobility enterprises to ensure the safety and compliance of their operations. By formulating relevant laws and regulations, the responsibilities and obligations of enterprises are clarified, and the legitimate rights and interests of users are protected. At the same time, the government can cooperate with enterprises to carry out

publicity activities to raise public awareness and acceptance of micro-mobility.

Finally, the government should also encourage enterprises to carry out technological innovation and promote the intelligence and environmental protection of micro-mobility tools. By establishing an innovation fund, we will support the R&D projects of related enterprises and promote the sustainable development of the micro-mobility industry.

9.4 Sustainability Strategy

Micro-mobility can better practice the theory of sustainable development. For example, in India, motorcycles and motor tricycles have long been blamed for the worsening pollution level in the country. From 2025, the Indian government will ban the sale of all non-electric two-wheelers and three-wheelers. This blank market will be filled by micro-vehicles. Currently, more than 11,000 new electric vehicles are produced in India every week. The introduction of these vehicles on the road will bring about environmental changes.

However, realizing the sustainable development of micro-mobility requires many strategies. The most important link lies in the enterprises that produce these vehicles. These enterprises should use environmentally friendly materials for production to reduce their impact on the environment. For example, many electric vehicle manufacturers have begun to use recyclable materials and bio-based materials, lowering the carbon footprint of their products. In addition, enterprises should also pay attention to energy consumption in the production process and try to use renewable energy, such as solar energy, to reduce the impact of production on the environment.

Secondly, the establishment of a resource recovery mechanism is an important link to achieving sustainable development. Enterprises can set up recycling points for used batteries and vehicles, and encourage users to send used products back for recycling and reuse. This not only helps reduce waste generation but also provides enterprises with renewable resources and reduces production costs.

In addition, it is crucial to promote the idea of long-term use. Enterprises can launch leasing services to encourage users to choose leasing instead of purchasing, thus reducing resource consumption. For example, in China, many services that share electric scooters and electric bicycles have realized on-demand rental, and users can choose the rental time according to their travel needs, avoiding the waste of idle resources.

9.5 Urban planning

Micro-mobility should be incorporated into the overall planning of urban transportation systems to enable more efficient traffic management and travel experience. Urban planners can design special non-motor vehicle lanes to ensure the safety and convenience of micro-mobility vehicles. In Germany, the transport planning department has added more and more cycle lanes, which has improved the safety situation for 65% of Germans, and more people will consider using bicycles, e-scooters, and e-motorcycles for their daily commute. In China, more and more newly built urban roads are also equipped with non-motor vehicle lanes. This kind of road planning can effectively reduce the conflict between non-motor vehicles and motor vehicles, thus improving the safety of cyclists.

In urban transportation systems, micro-mobility can be used as a complementary tool for public transportation. Through the integration with the public transportation system, users can find shared electric scooters near subway stations or bus stops, which is convenient for them to complete the last mile of travel. This model has been successfully applied in many cities in China, and users can easily find and rent electric transportation through mobile apps.

Fig 14 Technical Parking Area for Sharing Bikes

The infrastructure construction of micro-mobility is also crucial, including parking spot planning, riding area division, and installation of charging equipment. Relevant departments should set up special parking areas to avoid traffic chaos and ensure the safety of cyclists. The management department should also consider the division of cycling areas to ensure the rational flow of micro-mobility tools in the city. In addition, relevant departments should also consider the charging methods of these electric vehicles. In China, shared electric vehicles rely more on manual battery replacement. At specific times every day, staff will find electric vehicles with low 6 power based on positioning and replace them with fully charged batteries. However, there seems to be a more efficient way in Paris, France, where Estonian startup DUCKT has conducted a pilot program in which the company launched 150 stops, using existing infrastructure such as street lamps, billboards, and bus stops to provide electrical energy to electric vehicle.

10. Conclusion

(1)Study Summary

This paper summarizes the present situation and future of micro-mobility and discusses its importance in urban transportation. It is found that micro-mobility can not only provide more convenient choices for travel but also effectively alleviate urban traffic pressure and promote sustainable development.

(2) Emphasize the importance of micro-mobility in sustainable urban mobility

Micro-mobility plays a very important role in sustainable urban transportation. By promoting electric transportation and sharing services, people can use more environmentally friendly modes of travel and reduce their dependence on traditional fuel transportation. With the advancement of technology and the support of policies, micro-mobility is expected to occupy a more important position in urban transportation in the future.

(3)Limitations of the study and future research directions and suggestions

The limitation of this study lies in the limited discussion on the definition and types, advantages, technical support, market status, and demand analysis, impact of policies and regulations, social impact, and challenges of micro-mobility. Future research can further explore the adaptability of micro-mobility in different urban environments, and how to improve user experience and safety through technological innovation. In addition, the research can also pay attention to the impact of micro-mobility on urban economic and social development, and provide a more comprehensive basis for policy formulation.

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