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Evidence-Based Smart Transition Strategies for Long-Distance Commuters in Beijing

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Building a sustainable and eco-friendly transport system is crucial to tackling global challenges such as climate change, as transport can be seen as one of the main sources of air pollution and CO_2 emissions in megacities, particularly in developing countries. By bringing together multiple modes of travel, and combining different transport provider options into a single service, Mobility-as-a-Service (MaaS) could offer an effective way to help build a sustainable city by improving public transport services. However, the strategies used to develop MaaS, vary in different cities based on their specific multimodal transport facilities and service. Many residents of Beijing have to contend with long-distance commuting, which may adversely affect individuals' travel experience and satisfaction and is, therefore, a key issue for transport development in Beijing. Using Beijing as a case study, we carried out in-depth interviews and thereby captured long-distance commuters' concerns and needs concerning their commuting experiences. Our findings show that long-distance commuters are primarily concerned about the following multimodal commuting scenarios: "Underground + bicycle", "Underground + taxi", "Underground + private car", and "Underground + bus". Therefore, we suggest that the priority should be to develop a MaaS model for Beijing that focuses on the integration of multimodal transport connected to the underground rail system.

Keywords: mobility-as-a-service, long-distance commute, public transport, multimodal change, integration, Beijing

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1 INTRODUCTION

Commuting, as a derived demand, is a sizeable portion of workers' day. Experiences during commuting modes and the commuting microenvironments (noise, comfort level, etc.) affect commuters' physical health as well as wellbeing level (Kessler et al., 2021). However, the combination of rapid urbanization and motorization has been placing an ever-increasing amount of pressure on the current transportation infrastructure throughout the world, which negatively affects the commuting experience (Liu et al., 2020). In addition, with the rapid urban sprawl, job-housing imbalance and the large-scale suburbanization, many megacities, such as Beijing, have seen increasing commute distances and worsening transportation conditions, e.g., traffic congestion, traffic fatalities and injuries, traffic pollution and increased energy consumption (Qu et al., 2021). Long-distance commuters tend to use more than one transportation mode such as "underground + bus" for their commuting journey. They suffer from low connections during modal shifts, long commute duration, less-developed transition and transport conditions (road congestion, public transport crowdedness, etc.) (Fan et al., 2021).

To overcome the problems generated by multimodal transportation, it is necessary to integrate all the public and active (e.g., sharing bikes) transportation modes. Public transport (PT) and active transport as shared, sustainable, and cost-effective travel modes contribute to improving urban mobility, reducing road traffic accidents, decreasing overall greenhouse gas emissions, and fostering more livable cities (Zhang et al., 2021).

Mobility-as-a-service (MaaS), could be seen as a way to better link multi-mode transportation in metropolises like Beijing. By bringing together multiple modes of travel, combining different transport provider options into a single service (e.g., an integrated mobile application platform), MaaS could offer an effective way to facilitate PT and develop a sustainable transport system (Jittrapirom et al., 2017). An integrated platform that combines multiple transportation mode services will allow commuters to complete the planning and payment for the entire trip at one time, which makes the whole travel process more straightforward and convenient, especially for those commuters who need to use more than one transportation mode at one trip. In addition, when it comes to the traffic connection problem between different transportation modes, MaaS can also solve the problem of "the last mile", greatly saving time for long-distance commuters, and therefore, improving their satisfaction with the seamless public and shared transportation systems. In this research, we primarily focus on the initial starting point of MaaS models using Beijing as an evidence-based area. The aim is to investigate how to improve the long-distance commuting experience through MaaS, and ultimately, use MaaS to provide ideas for sustainable transportation development in megacities like Beijing. Thus, the research questions are summarized as below: 1) what are the concerns, needs and values of MaaS for long-distance commuters in Beijing; 2) how could MaaS be promoted in improving long-distance commuters' experiences and achieving sustainable transportation.

This study differs from previous studies in the following manners. First, in the recent increasing strand of literature, they mainly explored MaaS from the national level and attempted to demonstrate the connections between MaaS and sustainable development in the transportation area (e.g., Canale et al., 2019). However, in this paper, we will explore MaaS from the perspective of megacities like Beijing rather than the national level, to investigate the proper MaaS model matching the various characteristics of one mega-city. As previous research mostly focused on the national level rather than deepening into a single city, local contexts are often ignored. MaaS development should be linked with its local characteristics, such as the public and active transportation infrastructure and local people's travel behaviour. Therefore, this study digs into a single megacity with an emerging MaaS strategy based on commuters' concerns, values and needs using bottom-up approach. Second, scholars highlight users' preference for the MaaS bundle, which is defined as a set of preferable travel modes for multiple trips in a trip (e.g., Kim et al., 2021). However, transportation is not like a normal business model, instead, it should consider its public benefits. Therefore, this research focuses on the real transportation conditions of long-distance commuters and their concerns and needs upon the MaaS. Rather than the business models, we connect MaaS and existing commuting patterns in Beijing, trying to figure out how Maas can alleviate long-distance commuting problems. Except for the sustainable development, this paper is to enhance public transportation satisfaction to promote commute quality in Beijing. This bottom-up approach focused on individual commuters' experience and responses can provide policy implications for policy-makers to put forward a more satisfied "underground+" mode MaaS strategy and achieve low-carbon commuting and environmentally friendly transportation.

This study is organised as follows. **Section 2** reviews the existing literature regarding the development history of MaaS and the necessities for commuting behaviour. **Section 3** introduces the study areas and methodology. **Section 4** presents the findings and discussion, while the final section summarizes the study and provides directions for future research.

2 LITERATURE REVIEW

2.1 The Development of MaaS

Traditional transportation system relies on transportation infrastructure and services. Nowadays, with digital and information development, MaaS can integrate traditional transportation systems and new production factors, such as digital technology. Since then, it combines a variety of transport services, such as the search, payment and booking functions within one system, which can help to support a shared transport system and improve sustainable urban mobility. The concept of MaaS was first put forward in Finland in 2014, and, since then, many other countries have made efforts to develop both concepts and applications of MaaS (Qin and Wang, 2020). Many megacities, including Beijing, are trying to find the best way to reform multiple public transport systems.

As an emerging concept that builds on a single, digital, customer interface to source and manage travel-related services (Henisher et al., 2020), MaaS is an essential way to improve travellers' experience. Passengers in megacities like Beijing have suffered worsening travel experiences because of disconnected transport facilities. MaaS can improve their well-being in many aspects, for example, reducing their travel time by integrating all the travel modes in one platform, eliminating unnecessary security procedures to lessen queue time and so on, which could increase their satisfaction during travel. Nevertheless, limited by digital technology and other reasons, it will take a long transition time to build a recognised and unique MaaS platform to achieve these goals.

Whim, a private Finnish mobility service provider owned by a group of Finnish national and international transport and mobility service providers, explored MaaS business models, and now provide people with the option to travel on the a-pay-per-ride basis (Aapaoja et al., 2017). Unlike Whim, some companies based in cities in the USA have primarily focused on technological development rather than MaaS

business models. For example, Moovit focuses on developing autonomous vehicles to improve customers' travel satisfaction (Santos and Nikolaev, 2021). Therefore, as this suggests, based on the policies, guidance and transport systems that operate in different cities, MaaS develops in unique ways, depending on the contexts and needs of a city.

Qin and Wang in 2020 compared MaaS development in different countries and pointed out that MaaS as a new integrative service can offer a pleasant travel experience for passengers, but transportation is not a typical market product, and the profit of service providers might not be attractive compared with other fields. Therefore, it is essential to understand different MaaS stakeholders' concerns, needs and values to promote MaaS to provide higher-quality integrated transportation services. Many research highlighted the importance of opening access to information and payment data services of transport operators for third-party resale and use (Karlsson et al., 2020; Liimatainen and Mladenović, 2021). Yet, data onboarding brings potential opportunities, but also risks and challenges. It is difficult to convince data owners to share their data because it may harm their existing profits, and the utilisation of data onboarding should also be fully investigated before use.

2.2 MaaS Development and Sustainable Commuting

Within the earlier studies in understanding the associations between daily travel behaviour (e.g. commuting) and subjective wellbeing had been primarily focused on limited aspects of travel behaviour, such as travel mode (Zhu and Fan, 2018), and there may be vital contrasts in commuter encounters of diverse modes (Chng et al., 2016). There are a growing number of papers discussing commuting satisfaction in different geographical contexts. For instance, an empirical study using the case of Beijing show that multimodal travel behaviour among commuters poses significant challenges to their travel satisfaction (Mao et al., 2016). Although single transport modes, such as the Underground, have been well developed, there is substantial dissatisfaction among long-distance commuters, particularly those who use various transport modes. This could be due to the fact that each transport mode is run by a different operator, and hence it is difficult to integrate them into one complete system.

Exchanging from car journeys under five miles to walking or cycling has the potential for sparing heart infection fatalities, it saves a number which is equal to the collective non-physical-activity heart illness prevention programs (Meng et al., 2016). Although PT has been improved, over the past decades, urban regions have many negative side-effects (e.g. air contamination, traffic accidents, greenhouse gas emissions, congestion, and health issues due to lack of physical activity), whereas behavioural change or modal shift can be regarded as a critical strategy to decrease the negativity associated with of unsustainable commuting behaviour (Zhang et al., 2019).

Whereas, a few of these side-effects can be somewhat abated by technological and design measures (e.g., developing cleaner and more efficient engines, improving the infrastructure). Many scholars view behavioural changes as an imperative technique to reduce the negative impacts of motorcar traffic (e.g., Hickman and Banister, 2014). However, most of our citizens declared that they have not partaken in any individual activity in the past to protect the environment, in spite of the fact that human activities, and convenient transportation in specific, have gotten to be fundamental reasons for climate change. Subsequently, even if most of us are well aware of the destructive impacts of our transport behaviour (e.g. using private cars for commuting) on the environment, little is revealed about how climate change might truly affect our lives and indeed less about our self-efficacy in handling this issue (Gössling and Peeters, 2007). Eco-friendly branding of modal shift does not show up as a persuading argument to change mobility practices (Handy and Thigpen, 2019). Instead, emphasising another cluster of results from using diverse transport modes, such as the level of protection, and comfort would be more convincing to trigger a modal shift towards cleaner transport modes (Ettema et al., 2016).

From the understanding of Beijing commuters' satisfaction in each mode, it is crucial to move from eco-unfriendly and non-active commuting modes (e.g. private cars) to economical commuting modes, such as PT, walking and cycling. According to the Annual Report of Beijing Transport Development in 2019, Beijing has already established an integrated MaaS platform, and customers can use it to plan their travel routes. In fact, over the past decades, expanded car activity in industrialized nations has driven negative side-effects mentioned above. MaaS could be a way to diminish the utilization of private cars and expand the number of individuals using PT through the scope of commuters' satisfaction.

3 METHODOLOGY

3.1 Case Study of Beijing

Beijing was selected as a case study area for this research. As one of the most representative big cities in China, Beijing has witnessed increasing commuting distances on average (Hu et al., 2018). Commuters have to spend more than an hour from home to the worksite on average, extensively longer than those in the other cities in China. There are 27 underground lines in operation in Beijing, with an operating mileage of 783 km and 459 stations (including 72 transfer stations) (**Figure 1**). Underground lines and buses are the major low-carbon travel modes provided by the local government. It can be more intuitively found that only 42% of the residents live inside the fifth ring road of Beijing, who are normally faced with a one-way commute distance over 9 km. For those residents living in outer suburban districts, they may even suffer from long-distance commutes exceeding 15 km. Long-distance commuters may feel anxious not only because of the longer commuting distance and time but also for the disconnected multimodal transportation and the lack of the information integration platform when changing their transportation modes. These make the residents more eager for the improvement of the quality of multimodal transportation than ever before. In addition, the MaaS platform in Beijing is mostly based on the "underground+" model, as most long-distance commuters using PT choose underground as their main commute mode.

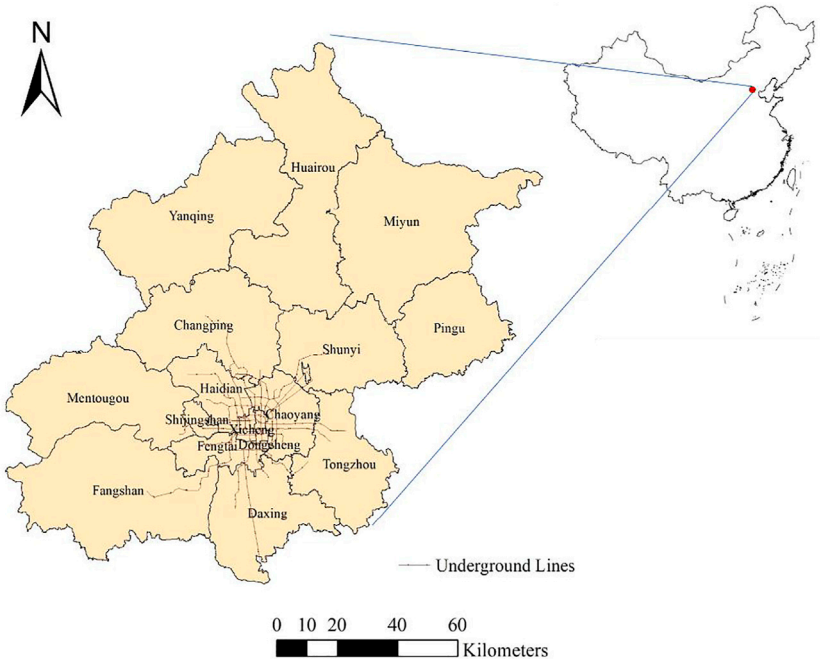

FIGURE 1 | Case study area.

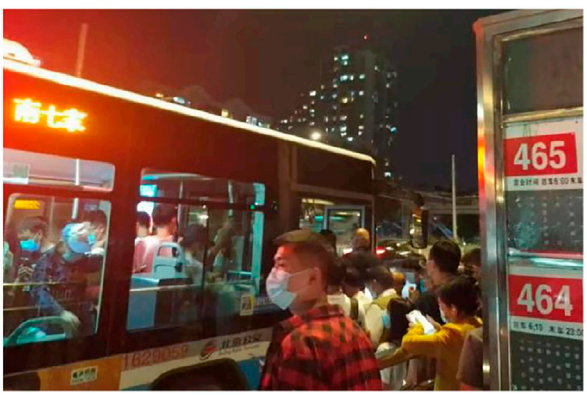

FIGURE 2 | Long-distance commuting situations in the case study area.

Figure 2 demonstrates the inconvenience caused by the change of transportation modes, where **Figure 2A** shows the long walking distance and congestion when making the transfer and **Figure 2B** shows the crowdedness at the bus station for those who make the transport mode change.

3.2 Data collection approach

In-depth interview, as a key bottom-up approach for policy-making process, has been a long-standing method to understand individuals' behaviour, experience, value and needs. A total of 30 long-distance commuters were recruited as interviewees in Beijing who volunteered to register in an online interview platform. Each participant was asked a series of open questions upon their commute conditions, experiences, concerns, values and needs through 40–60 min of telephone calls. In this research, interviewees were divided into three categories based on their frequency of green trips per week. Participants comprised males and females aged between 21 and 55 from various backgrounds and with differing long-distance commute experiences. Thus, they were representative of a wide range of individuals. **Table 1** provides a summary of basic demographic information about the participants.

3.3 Thematic Analysis

Thematic analysis is used in this study, as a basic qualitative methodology to figure out the patterns or themes. It has the

TABLE 1 | Profiles of participants.

Gender	Career	Marital status	Education	Income	Green trips frequency per week
Female	Student	Single	Bachelor	Low	4
Female	Student	Single	Bachelor	Low	4
Male	Company employee	Single	Bachelor	Average	12
Male	Student	Single	Master	Low	8
Male	Researcher	Single	Master	Average	10
Male	Company employee	Married	Bachelor	Average	12
Female	Company employee	Married	Bachelor	Average	12
Female	Engineering	Married	Master	Average	10
Male	Researcher	Single	Master	Average	12
Female	Sales	Single	Below the high school	Low	12
Female	Engineering	Single	Master	Average	10
Female	Company employee	Single	Bachelor	Average	12
Female	Nurse	Single	Bachelor	Average	10
Female	Scientific researcher	Single	Master	Average	10
Male	Engineering	Single	Master	Average	10
Female	Company employee	Married	Master	Average	8
Male	Company employee	Married	Bachelor	Average	12
Male	Company employee	Married	Bachelor	Average	12
Female	Scientific researcher	Married	Master	Average	10
Female	Sales	Married with children	Bachelor	Average	4–8
Male	Company employee	Married with children	Bachelor	Average	8
Male	Worker	Married	Below the high school	Low	14
Male	Executive	Married with children	Master	High	0–2
Male	Company employee	Married with children	Master	Average	12
Female	Communication manager	Married with children	Bachelor	Average	4–8
Female	Engineering	Married with children	Doctor	Average	10
Male	Contractor	Married with children	Bachelor	High	2
Male	Scientific researcher	Married with children	Doctor	High	2
Female	Publisher editor	Married with children	Master	High	0–2
Female	Cleaner	Married with children	Below the high school	Low	10

merits for scientific summary and data reduction from complex and long texts. We aim at identifying the themes (patterns in the data which are important or interesting). subthemes were pre-chosen, for instance, commuters' mainly travel behaviours such as 'underground + private car', 'underground + taix', 'underground + bike' and 'underground + bus' were chosen for analysing their commuting concerns, behaviours and needs.

4 FINDINGS AND DISCUSSION

4.1 Commutes' concerns

Commuting is essential for accessing key life activities. Long-distance commuters are faced with longer commuting times and having to negotiate complex transport systems and conditions. Perhaps surprisingly, according to the answers to the question, "would you like to teleport?", only a few commuters said they would prefer to teleport to their destination instead of commuting to the workplace at the site. The desire to spend time travelling seems counterintuitive, but people appear to feel that the process of getting to their destinations is enjoyable or fulfils some sort of function for them, whereas teleporting would deny them the journey experience (Ory and Mokhtarian, 2006). Most interviewees admitted that they would still like to commute, even if they could work from home. Clearly, transport is a demand derived from activities, and travelling from one place to another, by nature, takes time. However, most of the commuters interviewed had concerns about factors that could affect them during their commute, such as health risks from pollution (air pollution, noise pollution, etc.), diseases (COVID-19), and road safety issues.

For instance, many commuters tried to avoid public transport during the COVID-19 pandemic (also known as coronavirus). The coronavirus, outbreak in December 2019, has spread rapidly worldwide. Due to social distancing, there has been a dramatic decrease in travel demand using private cars rather than PT. In addition, an increase in home learning, e-learning, and a significant reduction in the number of public activities and social events have also reduced the need to travel. Although the pandemic situation is now under control in Beijing, some commuters are still worried about the risk of infection when using public transport.

"I prefer to use private vehicles and even walk, rather than using public transportation … though there are no new (COVID-19) cases in Beijing, I would still like to avoid public transport".

(Female, 40-year-old, 1 May 2021).

In addition, long-distance commuters probably have more concerns about their overall travel experience. For instance, commuters who only use one or two public transport modes

are more likely to be less satisfied with their journey compared with private car drivers or passagers. However, commuters who need to switch between different transport modes more than three times are often the most dissatisfied, even though their total travel time may be relatively short. In comparison between a trade-off between commuting time and fewer travel mode changes, people tend to choose the latter.

"I have two travel/route options to go to work: one is to use the Underground, which takes around 2 hours for commuting. The other one is to combine the Underground and the bus, which would only take around an hour. However, walking from the Underground station to the bus station is inconvenient. Although the latter is less time-consuming, I still prefer to choose the first option. Furthermore, I can read books/articles when using the Underground, while I would not be able to do this when taking a bus."

(Male, 30-year-old, engineer, 21 March 2021).

Many commuters choose the Underground as their main commuting mode, because Beijing's Underground network is well developed, which can provide a reliable service, and enable commuters to get to most areas of the city.

"Using the Underground is very enjoyable. I need to change three times within the Underground stations, but changing inside is not difficult. I quite enjoy both using the Underground and the changes at the Underground station."

(Female, 45-year-old, teacher, 23 March 2021).

Many residents choose to live near Underground stations, because the Underground can enable them to access their key life activities, even though it may also lead to some transport-related social inequity issues, even though people have similar levels of accessibility to the nearest Underground stations (Cao and Hickman, 2019). According to the results of the interviews, most of the commuters have major concerns regarding their experience when using the Underground in combination with other modes of public transport. Therefore, it is important to improve the Underground service to accommodate long-distance commuters' travel needs.

With serious home-work separation issues, commuting in Beijing is not only a time-consuming activity, but people also have to endure the inconvenience of changing transportation modes. Based on the existing traffic situation in Beijing, developing a transit-oriented development (TOD) can reduce the traffic pressure for the whole city as well as the commuting time for individuals. However, TOD system still has some tough problems to be solved.

PT's dilemma is that although it can decrease travel time to some extent, it also brings some problems like connecting and transferring among multiple transportation modes, which will dramatically influence the travels' experience. There are two main ways to transfer when travelling, intra-station transfer within the same mode of transportation and interchange between multiple modes of transportation, while for most travelers, the latter method is quite miserable compared with the former one.

A female participant, aged 26, admitted that she ". . .needs to transfer three times on a one-way commute every time. But because all of these transferring behaviours can be accomplished within the subway station, I feel it is acceptable in general". But the conditions are completely different for those people whose commuting involves interchange between many transportation modes.

"I have to combine subway, bicycle and bus to get to work every day. When I get out of the subway station, it is still 1.5 km away from my company, so I have to ride or take a bus to my company. The whole process is torturous because whenever I'm out of the railway station, I either have to wait a long time for the bus and cram into the bus with a bunch of people at the risk of failing to get on the bus, or I have to find a shared bike to get to my office, but things might happen when I cannot find any bikes to help me. Sometimes it is even better walking to work."

(Male, 25-year-old, researcher).

Unfortunately, it is common that use more than one transportation means within one trip, especially for commuting, no matter if the commuters live far or close to their workplace. For those commuters whose houses are close to work, they always face some problems, for example, not being able to find a shared bike, or not being able to find a parking space conveniently.

"My house is three–four miles away from the subway station, so I need to ride a bike to the station first, and then change to subway to my company. I feel there are still a lot of inconveniences. The first one is that there is not a fixed area for the shared bike to park around my house, so it all depends on luck whether I can find a bike or not. Even if I can find a bike to the station, it is also very difficult to park it around the station and sometimes I also cannot choose the direct route because some parts of the roads are not in good condition. In addition, there is not one app that can combine all of these transportation modes, which makes it really troublesome to switch back and forth among different apps. It will save a lot of time if I can complete the whole payment process just through one single app".

(Male, 26-year-old, company employee).

For those commuters who live far away from their workplace, there are more issues involved. For example, more waiting time and bad conditions may be included if their commuting process needs other public transportation means to connect to the underground stations.

"Because I live far away from my company, so I need to take bus to railway station every morning, and change to subway at the station. It can work well in summer, but it will become unbearable in winter. Because I get to work early, the bus frequency in the early morning is a little low and the weather is also very cold. It is really uncomfortable when waiting for the bus for a long time in such cold weather in the morning."

(Female, 27-year-old, company employee).

For this "underground + bus" scenario, customers always suffer from this long and uncertain waiting time. The same problem is as well applicable for those commuters who need to drive to help them accomplish the whole commuting process, which can be categorized as "underground + private car" and "underground + taxi".

A male participant, aged 33, said that he ". . .need to drive to the 'P + R' parking lot near the railway station first, and then go to work by subway. But no matter I arrive there early or late, there's

TABLE 2 | Concerns and expectations for four scenarios.

	Common Concerns	Different Concerns	Expectations
Underground + bus	Poor connection	Bus waiting time is too long; Uncertain bus waiting time	Increase the frequency of buses during rush hours; Add electronic stop sign to improve the visibility of bus location
Underground + bike		Unable to find a bike (lack of capacity); Difficult to park; Need to take a detour because of the bad condition of the road; Integrated payment problems	Fine operation and deployment of the bike; Strengthen the infrastructure maintenance; Realize integrated payment
Underground + private car		Parking congestion; Parking information is difficult to demand; Integrated payment problems	Increase P + R parking lot; Add P + R parking lot information query service to facilitate the query of its location and remaining parking space and other information; Realize integrated payment
Underground + taxi		Difficult to take a taxi;Difficult to find the appointed taxi; Integrated payment problems	Precise navigation for passengers from their location to the agreed departure point;Reasonable allocation of capacity according to real-time demand;Realize integrated payment

always a queue to get into the parking lot. But I still have to come early for using this 'P + R' lot, because if I park in the surrounding parking place, the price will start at 10 yuan per hour, rather than two for 'P + R' lot." For those people who use "underground + taxi" for their commuting, they don't have to waste time parking their private cars, but they often waste a lot of time taking taxis.

"After I get out of the railway station, I still need to take a taxi to my office. But it is hard to get a taxi during the peak hour. I always need to wait for a long time for the taxi drivers to take the order. And I often cannot find my drivers when I am out of the station. Also, it will be more convenient if we could integrate the payment for these two transportation modes so that I don't need to switch app all the time".

(Female, 30-year-old, company employee).

Above all, it is obvious that no matter the customers live near or far from their offices, they all hope to have an app that can integrate various transportation tools so that it can allocate the whole transportation system reasonably, and help the commuters plan their travel and complete their payment process as a whole. There are four scenarios while commuting, **Table 2** summarizes the common and different concerns for these scenarios from the commuters. It is obvious that the poor connection between different modes of transport is the main concern for most of the customers. At the same time, due to the lack of information sharing between different systems of travel modes, travellers have limited access to the information, so they always face problems like long and uncertain waiting times, unable to find a proper transportation mode to complete the trip and so on. Therefore, the MaaS platform is very urgent for Beijing citizens, especially the long-distance commuters, to help them build an information-sharing transportation app, where people can plan their trips and finish their payment as a whole, and enjoy adequate transportation information to help them make the decision. Here we also summarized the commuters' expectations for these four scenarios (**Table 2**).

For those people who live outside of Beijing, but still need to commute into Beijing for their work, their commuting is more time-consuming. These commuters have to take a high-speed railway first to travel from their own house, which is usually tens of kilometres away, to Beijing, and change for other public transportation modes like bus and railway to their company. They need to queue for a long time to go through security two times for each one-way commute. It is unnecessary and a waste of time for those people. However, once MaaS integrates all of these traveling modes, this repetitive work will be greatly reduced and commuters, therefore, can spend less time on their way to work. Commuting significantly impacts well-being at both objective and subjective dimensions at present (Lorenz, 2018; Ye and Titheridge, 2017). However, developing the MaaS platform in Beijing which is mainly based on the rail transit system can lighten the commuters' burden while transferring as well as increase their mental happiness.

4.3 Characteristics of MaaS Development in Megacities

4.3.1 Travel Characteristics

Knowing commuters' concerns towards the transportation system, the characteristics of MaaS in Beijing should be extracted to identify MaaS development in megacities. Firstly, as mentioned in **Section 3**, commuters' travel distance in megacities is larger than the other cities, which requires a combination of different transportation methods. Commuters suffer from the inconvenient experience of modal shifts.

"My home is about 15 km away from my workplace. I also have to ride a bike or take a bus to my office after taking the subway. I have nothing to do during my commuting journey"

(Male, 25-year-old, researcher)

Secondly, commuting in Beijing is mainly based on the underground and it usually takes a long time for people to work. Commuters rely on underground as well as the other modes, which means the process of modal shift is also time-consuming. Commuting time is daily consumption.

"Because I live far away from my company, and I don't have my car, I usually decide to go to work by subway considering the rush hour in Beijing. I need to transfer twice for each trip, and it will take me about 3 h to commute every day."

(Male, 28-year-old, engineer)

Thirdly, commuting time refers to rush hour, and the traffic flow in Beijing is very large. When commuting, all kinds of traffic facilities are crowded from parking lots to public transportation. Commuters tend to feel uncomfortable and exhausted while commuting.

"I need to drive to the "P + R" lot every day, and then change to the subway to my office. There are a lot of commuters, therefore I

always need to queue to enter it in the morning. Once I take the subway, I can barely find a place to sit down. The station is also crowded."

(Male, 33-year-old, company employee)

4.2.2 Expectations for MaaS Development in Megacities

The traffic flow in megacities like Beijing is extremely large in rush hour, so if we want to reduce the commuting time as well as alleviate the traffic congestion, public transportation always comes first. Using public transportation can also reduce carbon emissions in our daily life. Compared with other public transportation modes like buses and taxis, Beijing's subway network has developed rapidly, and it is much faster and more punctual, which can well cater to the needs of the commuters. So the main problem is how to coordinate other transportation facilities for MRT service to make using the subway more convenient.

"At present, the subway is still the main way for people to commute. I hope that if Beijing develops MaaS, the subway can be the core of it, and all other transportation methods can serve the subway, to strengthen the connection between the subway and other transportation modes. For example, the bus schedule time can coordinate with the arrival time of the subway, so that we can take a bus at the bus station successfully as soon as we get out of the subway station, which can meet the real-time needs of subway passengers."

(Male, 30-year-old, company employee)

Commuters in Beijing are often faced with transferring between multiple transportation modes, which always make them feel confused and tired while operating on different network platforms.

"At present, the apps for subway, bus and bike are all different. It feels troublesome to switch back and forth among these platforms. It will save a lot of time after realizing the transfer without feeling, for example, accomplish the payment for different transportation modes in one software."

(Male, 26-year-old, company employee)

Except for the combination of different modes of transportation, it is also expected that MaaS can also provide personalized travel plans. Currently, the routes offered by navigation software in the market are based on the shortest path and the shortest time. But personalized navigation software can meet the needs of users to a greater extent. For example, a male executive, aged 35, hoped that "personalized navigation can be realized in the future. For example, when we drive out on weekends, it can recommend a more beautiful driving route for us. When we drive to work, it can recommend a road that takes the shortest time; When we go shopping, it can automatically look for food streets and parking lots around the business circle. In short, I hope it can offer a more humanized service."

There exists a very obvious problem in the Beijing traffic system, which is the poor connection between different modes of transportation. After MaaS integrates the whole transportation mode, it can achieve a balance between demand and supply from spatial and time dimensions. By predicting traffic flow at peak hours, MaaS can allocate the capacity of specific areas reasonably, so as to reduce the time people spend looking for transportation as well as improve their satisfaction towards the whole system.

"Hopefully there will be smooth connections between bike/bus/taxi when I arrive and leave the subway station. Especially in the rush hours in the morning and evening. All kinds of traffic modes have obvious tidal phenomenon, so people in certain areas often have no bikes available. At present, even if we can dispatch some bikes, the capacity can still not meet the large demand generated in a short time. Therefore, it is hoped that intelligent prediction can be realized in the future, especially in the morning and evening peak periods, to instantly predict the passenger flow and realize the scheduling of transport capacity, so as to meet our needs for different transportation modes. What's more, it is always hard to grab a taxi when I departed from the underground station. It will be good if I can book a taxi ahead using the integrated platform"

(Female, 26-year-old, company employee)

The long-distance commuting problem is mainly caused by the separation of jobs and residences. By combining the TOD with the MaaS platform, we can reduce the distance between the living and working, so as to help commuters save time in commuting.

"At present, the separation of work and residence in Beijing is still very serious. I hope Beijing can also develop the TOD model and build a "mixed-use" community that integrates work, business, culture, education and living, so that we can meet the basic needs of life such as commuting, going to school and seeing a doctor nearby"

(Female, 26-year-old, scientific researcher)

4.3 MaaS Development Combined With Four-Underground Scenarios

Based on the well-established underground network in Beijing, the MaaS platform should also coordinate other transportation modes for a more comprehensive service for commuters. Combined with the characteristics of the Beijing transportation system, commuters' concerns and expectations, the development of the MaaS platform in Beijing will have different requirements under different scenarios, which are "underground + private car", "underground + taxi", "underground + bike", "underground + bus".

4.3.1 Underground + Private Car

Commuters who live outside the fifth ring are more often using private cars because their commute journey is always long. Yet, Beijing is developing parking and riding (P + R) projects, which means that many underground stations own parking lots, and commuters can drive the car to the underground station, and then use the underground to commute. But it is always time-consuming for drivers to queue to get into the parking lots. Thus, parking lots like this should also be integrated with the MaaS platform in Beijing, as a part of smart parking, making it possible for drivers to reserve parking spaces online as well as accomplish the payment through an integrated platform.

4.3.2 Underground + Taxi

However, those commuters who live outside the fifth ring but without cars, always rely on car-hailing or taxis for work in Beijing. Yet, during peaking hours, it is very hard to get a taxi. Under such concerns, MaaS can dispatch the taxis in advance through the realization of integrated planning. For example, after being informed of the departure and arrival time of the subway as well as the flow of commuters, MaaS can instruct taxi drivers to prepare ahead of time at the station. It is a win-win strategy for both travellers and the environment. As for the commuters can receive better and smoother service in less time. As for the environment, by reducing the time for taxis to drive empty while waiting for the orders, the implementation of MaaS can thus decrease Carbon emissions, which is rather eco-friendly.

4.3.3 Underground + Bike

Many people who live not so far away from the underground station would like to use sharing bicycles to reach the underground station. This is the scenario named "underground + bike". The requirements for MaaS under this scenario are more than the advance dispatch of bicycles, but also need to offer the service of navigation and reservation of bicycles. For instance, during peak hours, the demand of using bicycles increases, predicting the potential usage of sharing bicycles is not enough for commuters, they would like to be navigated to the specific locations of the bicycles and hope to use the reserved car immediately, instead of wasting time hunting for a bicycle in good condition that no one is using.

4.3.4 Underground + Bus

Commuters who live far away from the underground station, cannot walk or use a bicycle to go to the underground station. Instead, choosing the bus is their preferred option. In Beijing, many communities run a customized shuttle bus between home and underground stations. This is the "underground + bus" scenario. Under such circumstances, customers would like to know more information about the bus, and they hope that there is only one application to be both used at underground and bus. In future, MaaS could also help buses achieve functions like "once commuters make the order online, a bus can come within a second".

5 CONCLUSION

This paper used in-depth interviews, analyzed long-distance commuters' concerns, needs and expectations for MaaS in Beijing, and ideas, as well as future directions for the development of MaaS in megacities like Beijing, were highlighted. This paper summarized the characteristics of the commuting and transportation system in Beijing. Based on these findings, we summarize the specific development path for MaaS, which is applicable for various commuting scenarios, such as "underground + private car", "underground + taxi", "underground + bike" and "underground + bus". The requirements for MaaS under these scenarios can help to solve the concerns of commuters to a large extent.

Overall, this research connected the MaaS to commuting problems in megacities, trying to use the integrated transportation platform to solve commuting and environmental issues. This research makes several contributions to the development of MaaS. From the theoretical level, it demonstrated that the development of MaaS should be based on the TOD mode, and mainly focus on underground development. From the practical level, this paper proved that by building a MaaS based on the underground, we can promote the development of sustainable transportation development through increasing the proportion of green trips and decreasing carbon emissions. This MaaS platform can also be helpful to develop TOD and control the number of private vehicle ownership. It is of value to integrate this bottom-up approach and top-down strategy in promoting MaaS. Meanwhile, this approach provides windows for policy makers to take more in consideration of individual commuters'experiences, concerns, values and needs upon MaaS.

However, there are still some limitations of this research. First, we only surveyed commuters' demand for transportation in Beijing at a limited number, which is not enough to fully develop the MaaS platform. Second, the concept of MaaS has not yet gained popularity, so the commuters might not have a deep understanding of it. Therefore, the future construction of MaaS should involve more people to see the extent to which the MaaS has been explored, and progressively refine the concept and the pathway of MaaS development in Beijing.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Written informed consent was obtained from the individuals of the identifiable images and interviewees, and for the publication of any potentially identifiable images or data included in this article.

AUTHOR CONTRIBUTIONS

Conceptualization, XZ; data analysis, ZZ and YZ; writing, XZ and WG; visualisation, CP and XZ; supvision, CP and QS. All authors have read and agreed to the published version of the manuscript.

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