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TRENDS OF MODE CHOICE AND PROMOTION OF SUSTAINABLE TRANSPORTATION IN MEGA CITY OF DEVELOPING COUNTRIES: A CASE STUDY FOR KARACHI

Summary. The aim of this research is to explore the current urban transportation system of a megacity, Karachi. It was done by analyzing the Public Transport (PT) route network and commuter's mode choice along with mode share. Four major arterials were selected for the study. Data was collected through field surveys and questionnaire-based survey. PT system of Karachi mainly consists of buses and minibuses. It was found that PT has 16% share in mode choice of Karachi's travelers, which is less than most of the metropolitan cities in the world, and it has been decreasing constantly over the years. Most of the private vehicle users consider PT to be inefficient and uncomfortable. However, there is a willingness to use PT modes if they can provide at affordable prices. The current PT users are captive and women riders, which are bound

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economically or culturally to use these modes. Other sustainable modes of transport such as car-sharing and walking do not have significant share in mode share as well. Focused awareness campaigns for promotion of these modes should also be initiated.

Keywords: mode choice, public transport, sustainable transportation, Karachi

1. INTRODUCTION

More than half of the world's population lives in cities (Heraa, 2013). The population growth in cities is expected to reach 5 billion by 2050 (UN, 2018). Urbanization brings economic growth along with the burden on infrastructure and limited resources.

All over the world, megacities experience a number of challenges, which are mainly because of the increasing human settlement in the urban area. One of the major problems is related to the mobility of people and goods. The development of infrastructure, to mitigate such issue, created many connected concerns.

The issue related to drastic change due to urbanization was addressed initially in the last quarter of the 20th century regarding global warming. At that time, the aim was to set up to safeguard the human environment for future generation in terms of sustainable development (UN Declaration, 1972). After having a proper definition of sustainability, it has become the main concern for decision makers, planners, designers and other stakeholders (Journeault et al., 2021). Following that, a multimodal approach has been adopted to satisfy the travel demand of commuters in all the megacities around the world, as shown in Table 1.

Tab. 1

Mode share division (%) in different cities

Year	City	Bike	Car	Walk	P T	Taxi	Cycle	3-wheeler	Others	Reference
2011	London	0.9	31.8	20.5	43.4	1.3	2.1			Economics, 2016
2012	New York	0.1	30	10.5	56.5	1.4	0.7	0.8		Economics, 2016
2012	Hong kong		6	44.7	44.3	3.8		1.2		Economics, 2016
2010	peninsular Malaysia	37.29	45.58		16.02	1.1				Chiu et al. 2014
2010	Dhaka		4.3	19.09	29.83	2.86		5.73	38.19	Nakshi and Debnath 2021
2010	Paris	5	20	15	51	4	5			Aguiléra and Grébert 2014
2010	Dehli	20	23	15	31	5	6			Khanna et al. 2011
2012	Shanghai	15	11	10	57.5	1	4			Guan and Xu 2018
2012	Beijing				39.8					Kensworthy 2017

2006	Mumbai				31.9					
2005	Prague				50.6					
2006	Taipei				18.6					
2007	São Paulo				54.5					
2015	Dhaka	15	8	3	19		3	3	49	Rehman et al. 2020

Apart from the number of challenges faced by the authorities to make the city sustainable (Goluchikov, 2011), the issue related to mobility is on high priority (Haghshenas and Vaziri, 2012). There are many concerns related to sustainability in the transportation system like the energy consumption, emission, carbon footprint and urban livability. Thus, the transportation system of a city plays a vital role in the sustainable urban environment (Valdes et al., 2016). Numerous attempts have been made towards the understanding of sustainable transportation system. Research indicates a number of points that could lead towards the sustainable development. Some of the studies concluded that social, economic (Valdes et al., 2016) and environmental aspects should be reflected in every planning process (Brugmann, 2021). Others consider urban mobility, socio-economic (Russo, 2022) and efficiency as a positive indicator of sustainable development (de Andrade et al., 2016). Usually, the mass transportation system is supposed to be the most sustainable solution because it covers all the major indicators like social, economic and environmentally friendly. There are still certain measures that need to be counted for successful mass transit projects, like the socio-economic class, which could be one of the main indicators as it is the main source of mobility for low-income class (Ha et al., 2020). Richardson called the transportation system as complex because it varies with the vehicle type, population, and behavior of the people (Richardson, 2005). It has also been observed that sometimes the transit system fails because of improper configuration (Hidalgo and Huizenga, 2013) with respect to the location and city (Lau, 2013), for example accessibility to the most demanding class of people and infrastructure availability and new design (Neirotti et al., 2014). The effectiveness and successfulness of Public and mass transportation system depends upon how well the dynamic characteristics of both demand and solution were addressed. Travel demand management (TDM) tools are commonly used for the better understanding and implementation of sustainable solution for transportation related issues.

Several TDM tools that were developed on the above-mentioned sustainability indicators have proven effective and highly successful to mitigate the transportation issues. Bus rapid transit (BRT) is a system used to effectively handle the PT, BRT in Bogota is one of the successful projects with forty-five thousand passengers per trip with the peak level of 3.5 million passengers per day (Guzman and Cardona, 2021). There are many sustainable measures that are used to encourage the mass transit use and, in contrast, discourage the use of private vehicles. Parking restriction in San Francisco, congestion charging in London, Car-free day in Bogota (Böhler-Baedeker and Hüging, 2012), and vehicle quota system in Singapore and Shanghai and number plate restriction scheme in number of cities are successful examples to improve transportation system towards sustainability (Todd, 2013). The developed countries have many efficacious stories but unfortunately the developing

countries could not comprehend the dynamics of transportation system which resulted in the poor mobility management system in most of the cities.

Karachi is one of the megacities with a population over 20 million (Shibaskari et al., 2019), which is growing at a rate of 6% (Baqa et al., 2021). Every day around 200,000 vehicles, including 112,000 heavy vehicles, enter or exit the city. Karachi has significant importance in the development of Pakistan, and it contributes about 65% of the national revenue generation (Raza, 2016). The first step towards sustainable transportation was taken in 1964 with the establishment of the Karachi Circular Railway (KCR) (Kiran and Qadri, 2021). At that time, the share of mass transit in Karachi was around 60%, which included 90% of bus share, and 10% was shared by train (Heraa, 2013). KCR served the city with 104 trips per day at a time headway of 30 mins until the late 1970s. During the 1980s, the service of KCR started deteriorating due to a lack of maintenance of locomotive and railway tracks. This negligence of the government towards maintenance along with improper ticketing system resulted in reduced passenger trips, poor fare collection, and revenue loss. In the late 1990s, when the population of Karachi reached 10 million, the daily trips of KCR dropped to 12 trips per day during peak hour, with a monetary loss of PKR 5 million per year (equivalent to USD 200,000 at that time). Due to continuous negligence, the KCR was closed entirely in the year 2000-2001 (KMTC, 2012). The share of public transport reduced to less than 50% in the late 1990s, which further depleted to 36% in 2008 (Raza, 2016). In addition to the inadequate and improper public transport system, the reduction in public transport was further accelerated due to more accessible car financing and the availability of cheap motorbikes (Soomro et al., 2022).

Several attempts were made to address the issues of transportation system of Karachi like reports from government stakeholders, road, municipal, traffic laws and other. Traffic safety issue was addressed by estimating road traffic accidents with the help of data provided by stakeholders. Some of these attempts have shown a high severity rate for crashes and underreporting issue of the crashes (Khan et al., 2022). Identification of issues related to transport policies regarding PT routes and pollution aspect addressed in some other studies. Some of these issues included lack of implementation of transit-oriented strategies, including the integration of land use planning (Anwar et al., 2024). Pollution caused by road traffic like noise and hazardous gas has been addressed many a time. Traffic has been reported as the primary cause of noise and air pollution, which is contributing more than some other land use related sources (Mehdi et al., 2011). Issues related to traffic management and delay have been addressed in some studies which found the causes of congestion linked with heterogeneous and poorly managed traffic of Karachi. In response to these issues, certain technical enhancements in traffic management systems have been suggested, including traffic signal optimization.

However, there is a lack of studies related to mode choice modelling for Karachi. Moreover, the studies which pertain to the determination of qualitative factors impacting the mode choice are not well-known for most of the developing countries. This study fulfills the gap by providing a comprehensive overview related to the current transportation system and travelers' behavior. It is believed that this study will provide valuable insights into the travel decision-making process due to the unique characteristics of the transportation system in Karachi. The findings of the study are expected to be applicable to other megacities in the developing countries.

2. DATA COLLECTION AND METHODOLOGY

As mentioned above, the study area for this research is Karachi. In this study, the condition of PT is evaluated. The data is collected from field surveys and face-to-face questionnaire surveys. The data collection was carried out during the first quarter of 2020, and it was before the COVID-19 restrictions were applied. Hence, this provides the basis to apply the results of this study to the current situation in which travel is carried out normally.

2.1. Field survey

2.1.1. Bus routes; network and routes of PT

Public transportation in Karachi is operated by the informal sector, which includes Buses, minibuses and chinchis as public modes. A bus refers to the vehicle with a seating capacity of 40 people, while a minibus has half its capacity. A chinchi has a seating capacity of 5-7 people. The Regional Transport Authority (RTA) is responsible for data recording and issuing route permits of PT buses and minibuses, and it was found that their record was not updated. A number of PT routes are not currently operated and some of them are operated on unauthorized routes. For the analysis of the route network of existing active routes of PT, a field survey was designed. This survey was performed along the network of individual PT to identify the routes. It also includes the coordinated recording along the network for measurement of individual PT route length.

2.1.2. Traffic video; traffic count and mode share analysis on four arterials

The second field survey consists of traffic video collection of 15 hours, which will be used in the analysis of mode share in Karachi Arterial. Survey was performed on four major arterials of Karachi which are Shahrah-e-Faisal (Arterial 1), Rashid Minhas Road (Arterial 2), University Road (Arterial 3) and M.A. Jinnah Road (Arterial 4). Data was collected from 7am to 10pm on a normal weekday on every arterial. The video was then analyzed using click counter software.

2.1.3. PT mode capacity, occupancy and availability data

In the third field survey, a public transport occupancy survey was also performed along with traffic video collection. For the occupancy survey, visual observations were made to study the occupancy in each category of mode of transport mentioned in table 2.

2.2. Questionnaire-based survey

2.2.1. Mode choice and behavioral study

The analysis of the behavior of commuters towards PT modes was based upon a questionnaire-based survey, which was performed using face-to-face interview technique. The data was collected from the number of bus stops on the arterials and collectors of Karachi. The objective of the survey was to collect the prospective of current users towards PT.

2.2.2. Level of service (LOS) for PT

The data of LOS of PT is collected during face-to-face questionnaire base interview. Three parameters were selected to reflect the LOS of PT. The response of the below-mentioned questions is converted to the corresponding Level of Service (LOS) using Highway Capacity Manual procedures (HCM) (Prassas and Roess, 2020).

Question 15: Availability measure (mins)
Question 16: Route segment accessibility, Hours of service LOS (Hours per day)
Question 17: Passengers loads at transit bus stops. (Person/seat)

2.2.3. Attributes of PT

The PT routes have different departure times, frequencies, and route lengths. A Field survey was designed which is based on the face-to-face interview from bus operators to determine the different attributes of PT routes. Some of the results from this survey are shown in Figures 1 and 2.

3. PT NETWORK ANALYSIS

3.1. Capacity of the existing PT network

Route network design has now been evolving by the inclusion of traffic modelling. Usually, the fourth step of four-stage travel demand modelling is used with the other planning tools to identify the need of new routes, planning for future infrastructure changes and also for operational aspect. Traffic assignment models are generally involved in the transportation system route design (Hensher and Stopher, 2021). PT routes have significant role in transportation system across the globe. The success criteria of PT also depend on the design of route and usually the low-income class areas are more attracted to high-income class areas (Moro et al., 2021). The best practice of designing PT routes is to work along with the urban planning, wherein designed land use will define the transportation requirement of the particular area.

In developing countries, unfortunately, the proposed planning does not take place in the proper manner. The routes are sublet by the regional transport authorities to the contractor who is responsible for the number of buses and types of buses on that particular route. The operator of such routes operates the PT in an informal manner without the demand analysis. The routes are usually developed when the new settlements increase and there is a clear demand for PT routes (Abdel Wahed Ahmed and Abd El Monem, 2020). This study will be the first to cover the PT route network of Karachi and estimate its capacity.

The classification of PT routes operating in Karachi, in accordance with their capacity/frequency, is shown in Fig. 1. The red color lines are the highly used routes of PT while green lines indicate the PT routes which are used comparatively less. It is noted that most of the sections of two main arterials of Karachi, i.e., Shahrah e Pakistan and Shahrah e Faisal have usage. These trends are indicated by the frequency of PT routes which are more on these two arterials. Moreover, the connecting minor arterials have lesser capacity than major arterials. Overall, the capacity map of the PT routes shows that PT has sufficient penetration in the city and almost the entire city is covered by the PT.

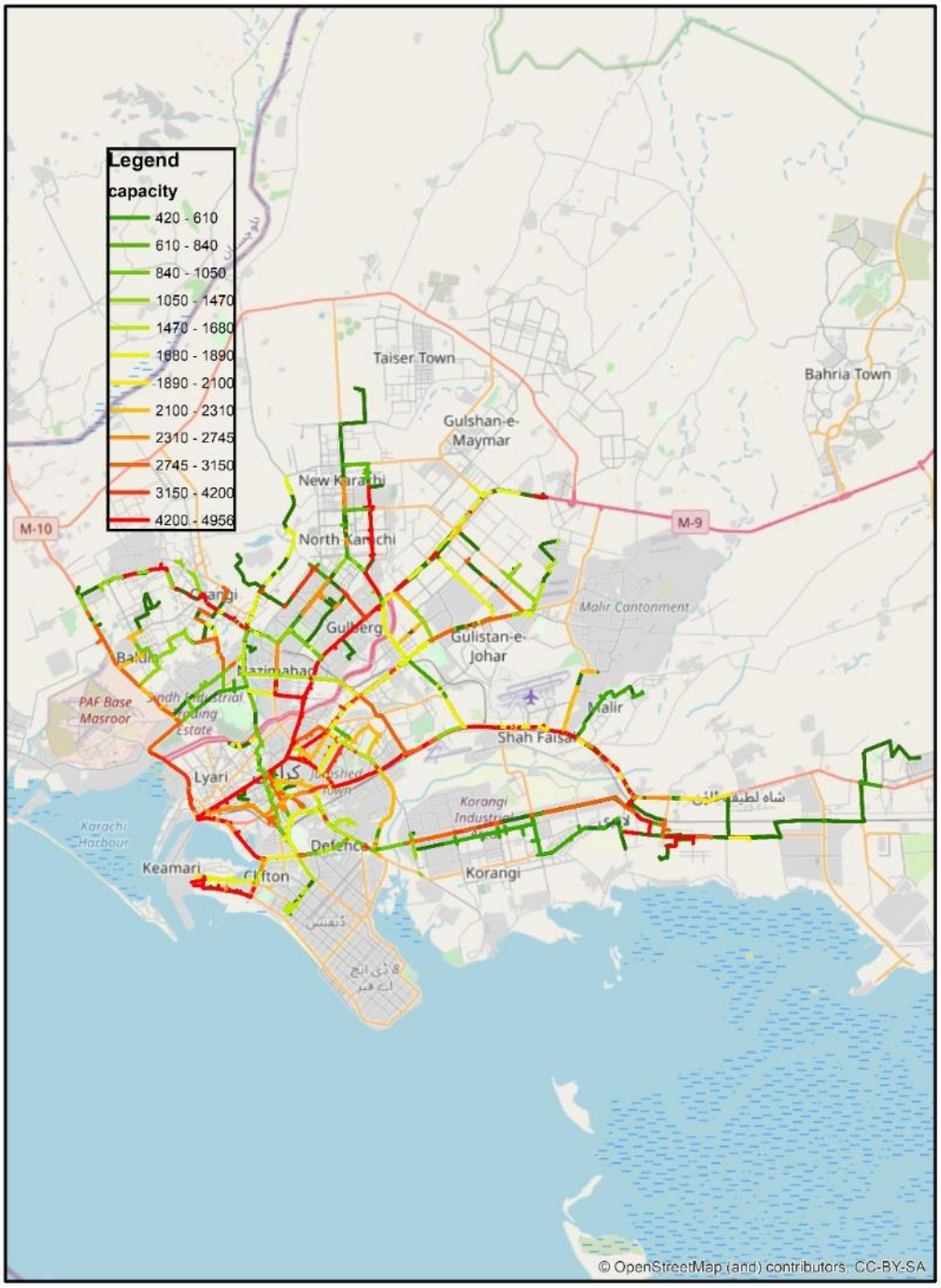


Fig. 1. PT routes network

There There are 53 PT routes operational in Karachi. Fig. 2 shows the frequency distribution of PT routes. 47% of PT are operating at 10-40 roads trips per day. While 33% of PT routes have 40-70 roads trips per day and the remaining have higher frequency of road trips per day.

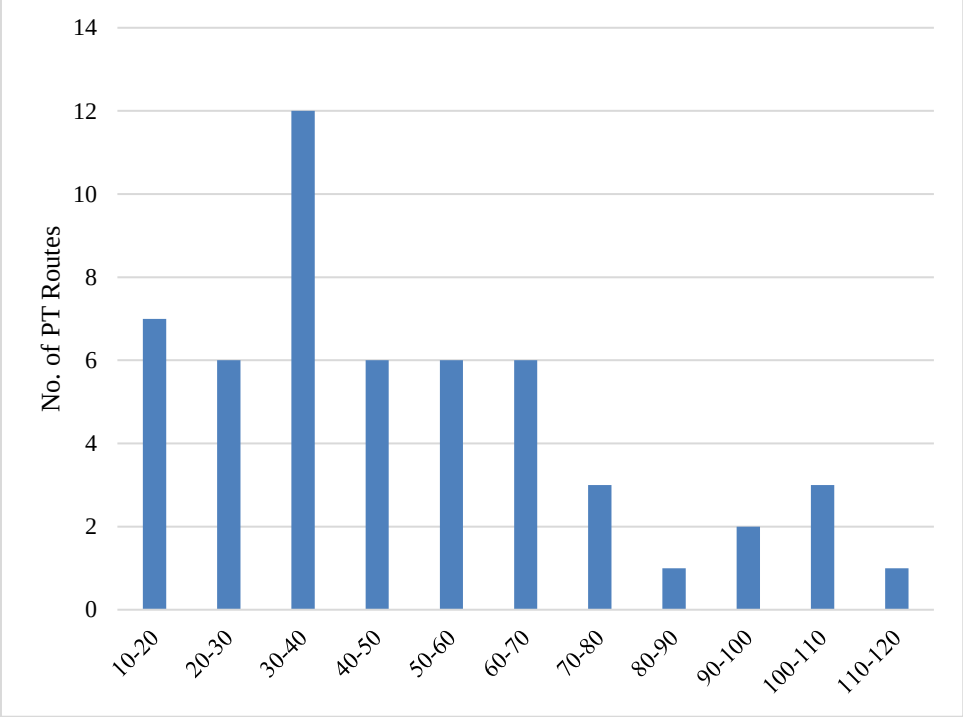


Fig. 2. Frequencies of PT routes

3.2. LOS of PT

As discussed in section 2.2.2, the LOS of PT is determined by three parameters. The result of the survey is shown in Fig. 3. 49% of PT users are satisfied with the availability of the PT and only 15% have issues with PT availability, shown with the rating of LOS A and B for this parameter. 62% of PT users found the route accessibility is adequate for them, as they have chosen LOS A, B or C for this parameter. Moreover, 70% of the commuters of PT (selecting LOS D, E or F) are not satisfied with the passenger load of PT and overcrowded PT was also observed in the survey. Therefore, overcrowding, or inadequate capacity, is the most prominent issue for the current system of PT in Karachi, which has been indicated in past literature as well (Shah et al., 2021).

3.3. Existing Mode Share

3.3.1. Occupancy and number of vehicles counted

PT always plays a significant role in the transportation system. However, sometimes due to lack of planning measures and operational management, it often faces lack of attraction which leads towards unsustainability. Vehicle occupancy is considered as a significant factor to analyze the behavior of users towards particular mode (Zhang et al., 2023). The analysis of occupancy of classified modes, at selected arterials, was also performed in this study.

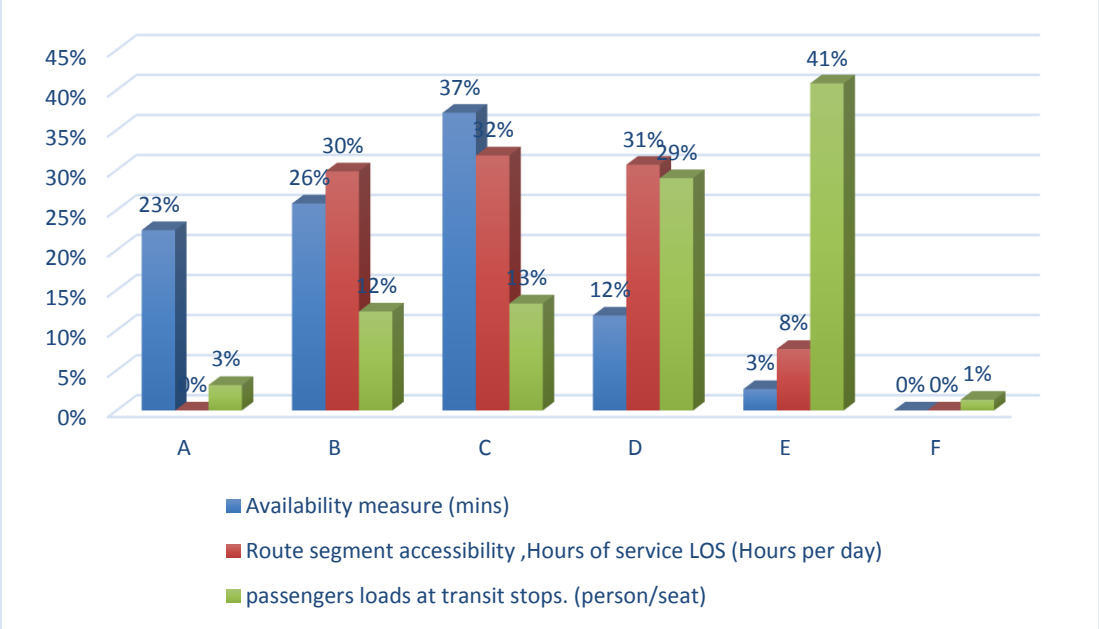


Fig. 3. LOS of PT

Average occupancy of modes was calculated by the field survey and recorded traffic videos for 16 hours on every arterial from 7 am to 10 pm. Buses are supposed to be the only mass transport mode for Karachi. Almost 95 percent of buses have the sitting and standing capacity of 40 passengers per bus. The average occupancy of the bus varies from 21 to 63 passengers per bus in morning and nighttime respectively in arterial 1 as shown in figure 3. It is observed that there is a significant change in average occupancy of buses in all four arterials, while the occupancies of other modes remain the same with slight variations. The average occupancy of car is in between 1.5 to 2.5 persons per car and the percentage of 4 persons per car is less than 10%, The occupancy of bike is in between 1.3 to 1.7 means the percentage of single user of bike is more than 60%, and the occupancy of chinchi varies from 3 to 9 passengers per chinchi in all four arterials as shown in Fig. 4-7 respectively. Furthermore, the behavior of chinchi user is different from other PT mode because it starts the trip when it reaches to its full capacity and usually travel on shorter route.

On arterial 2, the average bus occupancy varies from 22 to 52 passengers per bus. It shows that there are two lower values which are after the morning peak hour and before the evening peak Fig. 4.

On the third arterial, the average occupancy of chinchi is almost constant at 5 pax per chinchi whereas the bus shows the variation of 25 to 45 pax per bus as shown in Fig. 6. The fourth arterial is supposed to serve institutions and serves mostly student. As represented in figure 6, there is a peak of pax per bus at around 1 to 2 pm which is clearly the off time of the majority of classes.

The average occupancy of bus varies on arterial 4 varies from 14 to 38 passengers per bus, as shown in Fig. 7. The occupancy for cars on this arterial is around 2 while that for bikes is around 1.5. For 3-wheeler, similar to buses, there is more variation in the occupancy ratios ranging from 6.3 to 2.3 pax per 3-wheeler. The peak occupancy is shown generally in the evening peak hours for all modes, except for chinchi, which has a peak occupancy in the morning peak time as well. This arterial is different from other arterials as it passes through the old city area of Karachi, which has mixed land use with high-density. This creates higher variation in occupancy rates for PT modes.

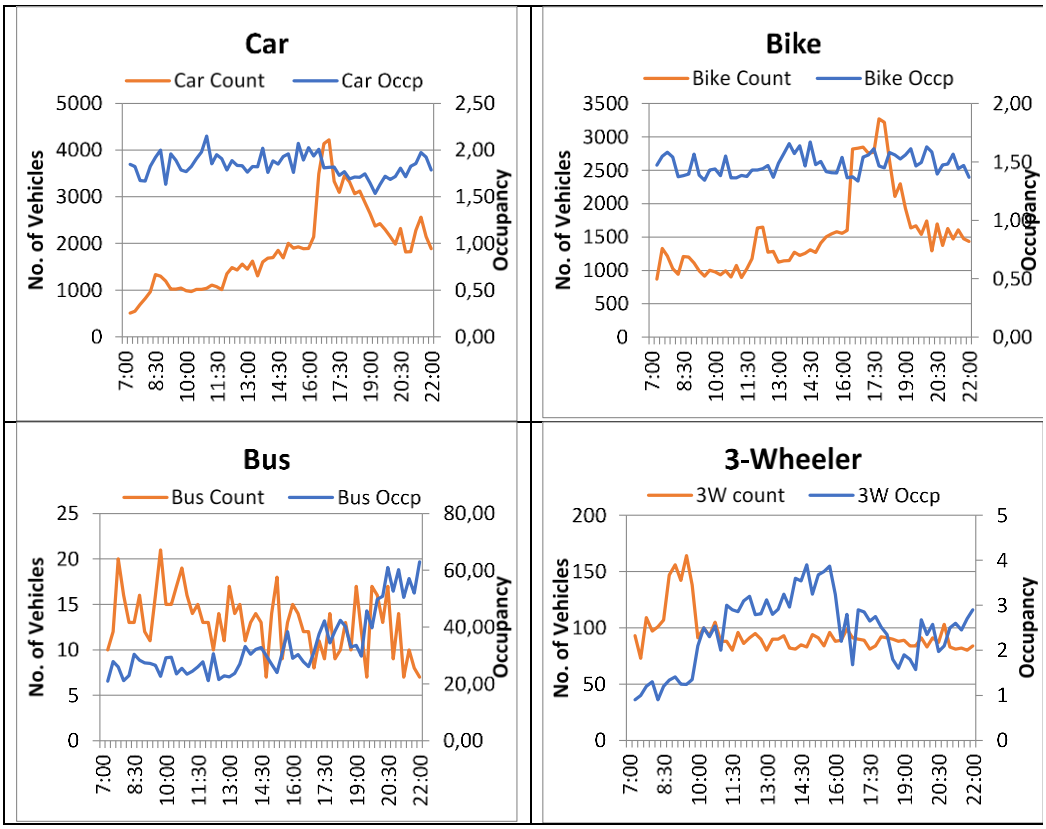


Fig. 4. Arterial 1 occupancy

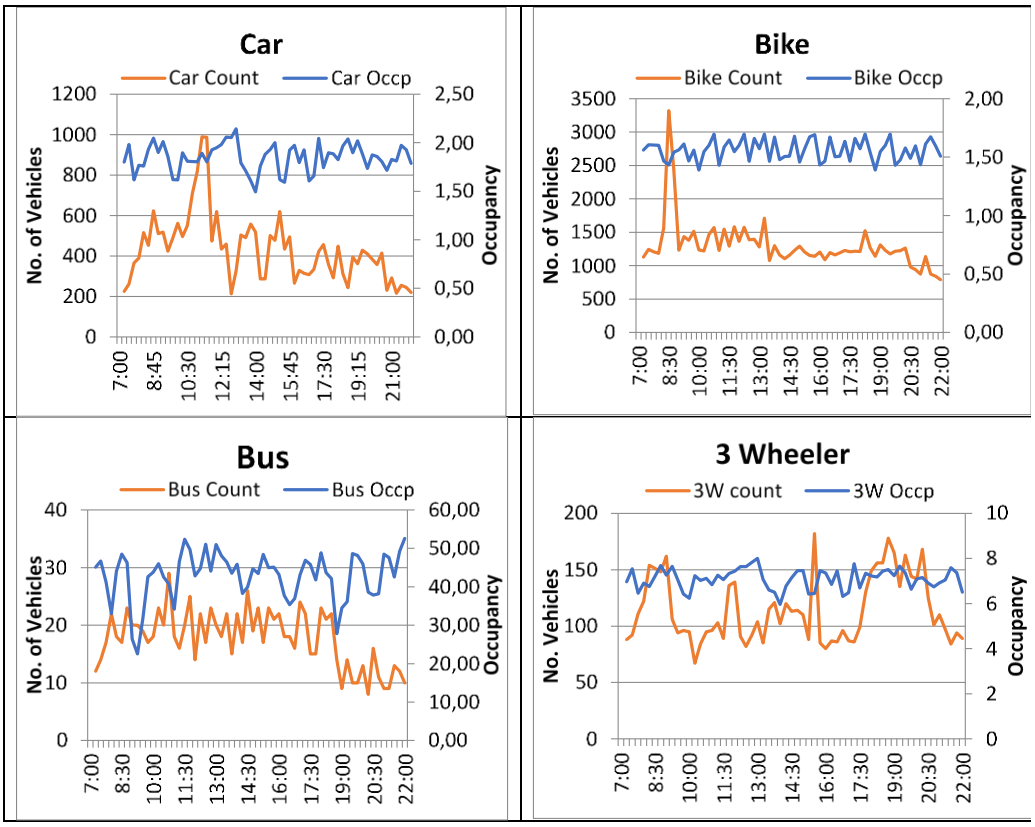


Fig. 5. Arterial 2 occupancy

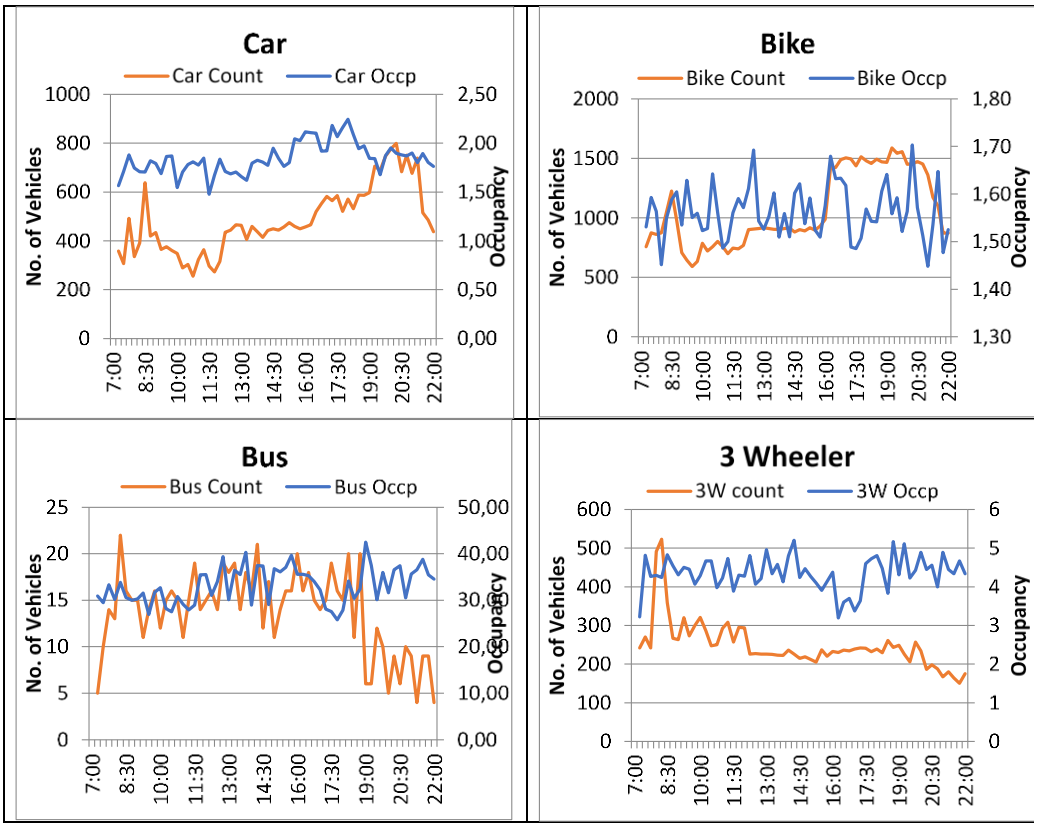


Fig. 6. Arterial 3 occupancy

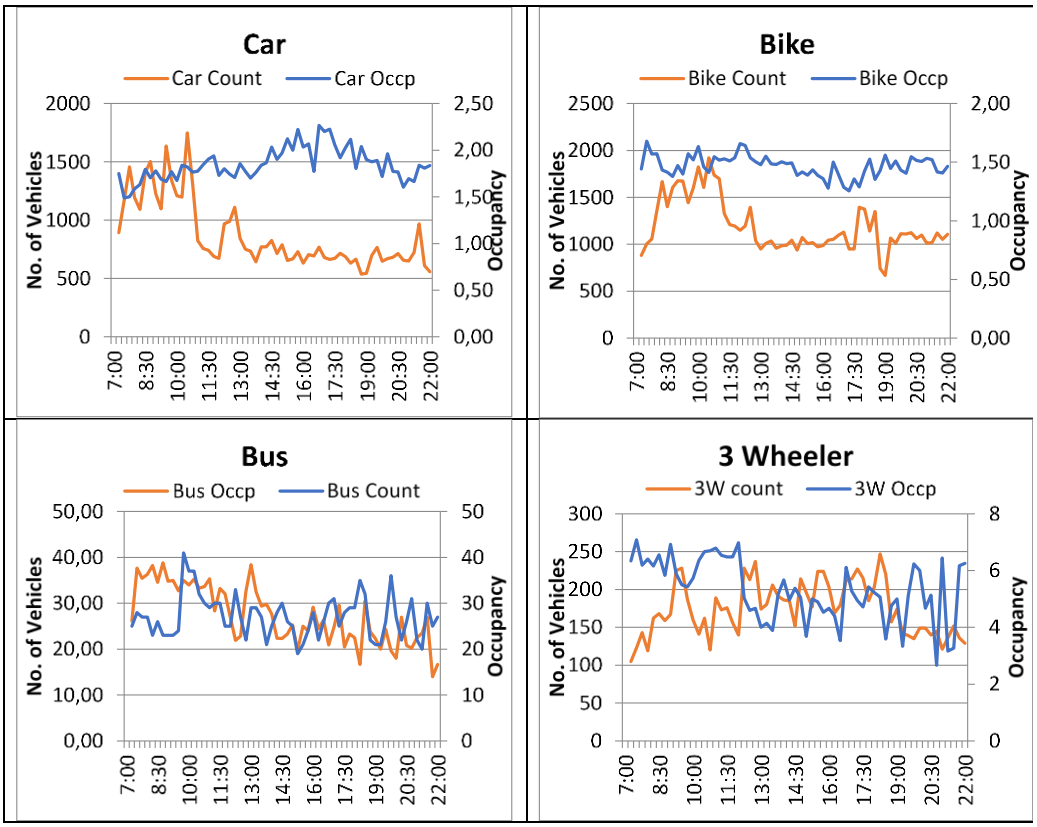


Fig. 7. Arterial 4 occupancy

3.3.2. Number of commuters per mode

In this section, the mode share of number of occupants and number of vehicles count of each mode is presented. This gives the understanding of the number of people using each mode on each arterial. Fig. 8 shows the maximum number of people, i.e., 0.2 million are using cars at arterial one whereas at arterial 2 only 48 thousand people are using cars. In addition to this, the amount of three-wheeler at arterial 1 is lesser as compared to the other arterials.

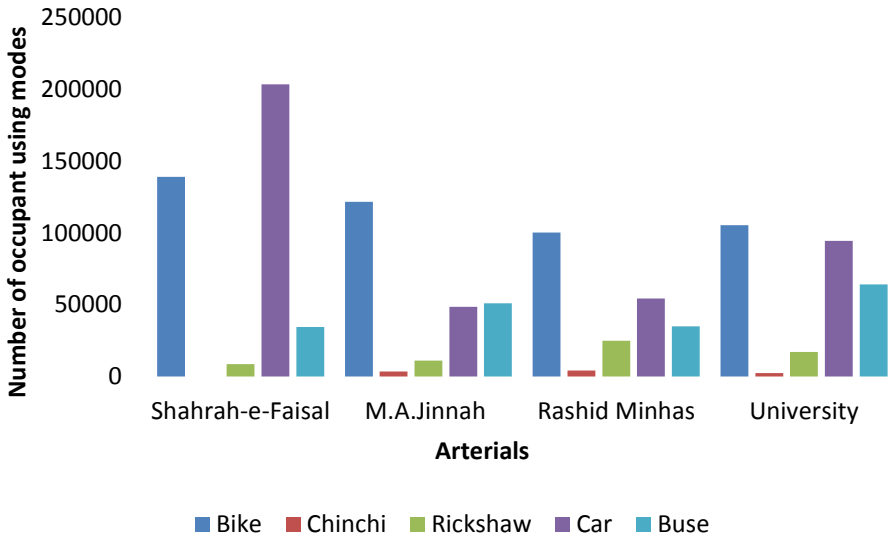
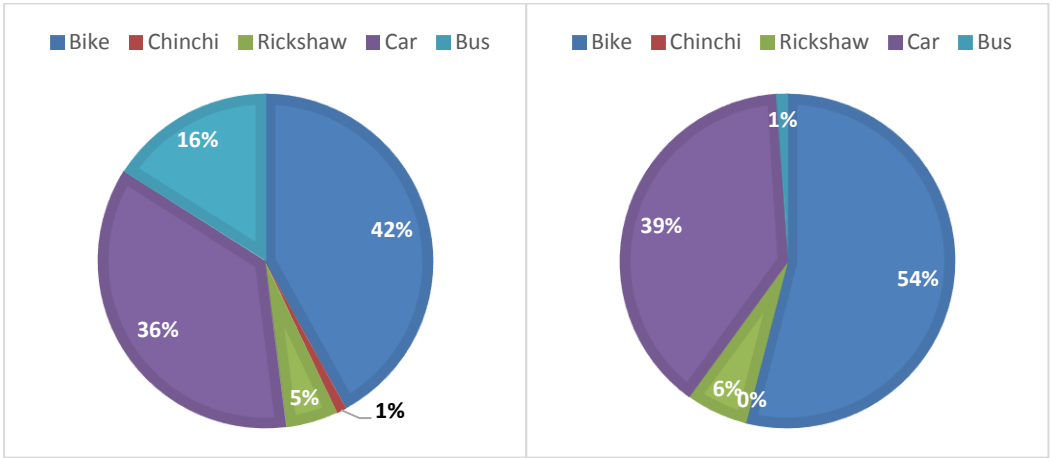


Fig. 8. Occupant mode share

The bus, which is supposed to be the most sustainable mode of transport, accounts for only 1% of the traffic share and carries 16% of the passengers, as shown in Figure 9. The ratio of the number of vehicles to the number of passengers for the car is 1.08, which means that the 1 passenger per car on all four arterial roads combined, and the 3-passenger space are not being used. Bicycles have two places and the average is more than 1, which means that bicycles are mostly used to their potential.



(a) (b)

Fig. 9. Occupant count (a) and vehicle count (b)

4. MODE CHOICE BEHAVIOUR

Econometric analysis is conducted to determine the mode choice behavior in the city by analyzing the association between mode choice behavior and socio-economic and demographic parameters. It also examines the reason of such behavior towards current and alternative mode based on three main attributes of a journey. Three main modes of transportation were considered public, car, and bike. 400 people from each mode were questioned explicitly about their current travel behavior and socio-economic data was also collected. Consequently, 1200 responses were collected.

The chi-square test is used to determine the association between the collected categorical data of socio-economic and demographic parameters. There are other measures used to determine the strength of the association, two of which are phi and Cramer's V. When both variables have only two categories, phi and Cramér's V are identical. However, when variables have more than two categories, Cramér's V is used to determine the strength of association (Baak et al., 2020).

The following subsections describe the relationships between socio-economic parameters such as gender, age, income, education, and mode choice. A summary of the relationship between categorical data and strength of association is presented in Table 2.

4.1. Age

As the survey was carried out at petrol stations and public bus stops using random sampling, the responses fall into one of four age groups (15-24, 25-54, 55-64, 65 and above). The chi-square test is used to determine the dependency between age and mode choice. The results of the test shown in Table 4 ($x2=20.907$, $df=6$, Cramer's $V=0.093$, effect size=weak) suggests that the null hypothesis can be accepted, and it can be assumed that there is no dependency between mode choice and age of the commuters in the city of Karachi.

4.2. Education

Respondents were asked about their level of education and the answers were recorded in groups (illiterate, primary, secondary, intermediate, undergraduate, graduate and postgraduate). Highly educated commuters are expected to earn well and prefer private vehicles (Abdullah et al., 2021). The chi-squared test ($x2=229.739$, $df=12$, Cramer's $V=0.309$, effect size=very strong) helps to understand the dependence of mode choice on the education of the commuter. These results indicate a strong relationship between education and mode choice. Therefore, the null hypothesis can be rejected, and the alternative hypothesis can be accepted. Moreover, a detailed examination of the data indicated that the highest percentage of people within the car mode belonged to the postgraduate group of education, i.e. 55.1%, and the lowest were from the illiterate group, i.e. 6.3%. Commuters of public mode were mostly from illiterate group, i.e. 57.8% and only 14.5% of commuters belonged to postgraduate level of education. Thus, it can be concluded that education has a strong relationship with mode choice in Karachi, which seems to be an indication of the difference in income between commuters of different modes.

4.3. Income

In a society with very different socio-economic parameters, income is expected to have a strong influence on mode choice (Ha et al., 2020). People with high incomes are expected to have private vehicles and not prefer public transport. The response of commuters was recorded in five groups of monthly income (PKR/month) based on Pakistan's income tax slabs. As a categorical variable, chi-squared test was performed. The results of the test show (x2=420.403, df=10, Cramer's V=0.419, effect size=very strong) a very strong dependence of mode choice on the income level of the commuter, proving that the null hypothesis should be rejected and the alternative hypothesis is strong enough to be accepted. The data shows that the highest percentage of people with an income of more than PKR 300,000 (approximately USD 1972, as of 16 May 2021) prefer to travel by car, i.e. 55.9%, and only 5.9% of people with a monthly income of less than USD 25,000 (approximately USD 164, as of 16 May 2021) could afford to travel by car. Moreover, public transport is most used by the group with a monthly income of less than USD 25,000, i.e. 56.2%, and only 15.3% of people with a monthly income of more than USD 300,000 were observed to travel by public transport. These results indicate a very strong relationship between the choice of transport mode and the monthly income of a commuter. These observations are in line with the expectations of researchers given the relationship between mode choice and education.

4.4. Gender

Out of 1200 respondents, 980 were male and 220 were female. Karachi has a smaller number of female cyclists. Only 5 female cyclists were found out of 400 randomly selected respondents, while 98.8% of commuters were male. Similarly, the car mode in Karachi is mostly driven by males, which is 70.3% out of 400. The results of the Chi-square test (x2=121.369, df=2, Cramer's V=0.318) show a very strong association between gender and mode choice. Therefore, the null hypothesis can be rejected and it can be concluded that mode choice depends on the gender of the commuter. Based on the above characteristics, it appears that the women included in this study are more likely to use public transport (Brohi et al., 2021).

4.5. Occupation

Responses of commuters based on occupation were recorded in five groups (Student, Employed, Self-employed, Unemployed, Retired). The results of the chi-square test (x2=14.454, df=8, Cramer's V=0.078) show a weak relationship between the commuter's occupation and the choice of transport mode. The null hypothesis shall be accepted, and alternative shall be rejected.

Tab. 2

Summary of statistical analysis

Factor	Dependent Variable	Statistical Test	Asymptotic Significance	Degree of Freedom	Cramer's V	Strength of Association
Age	Mode choice	x^2=20.907	0.002	6	0.093	weak
education	Mode choice	x^2=229.739	0.000	12	0.309	Very strong

Income	Mode choice	x^2=420.403	0.000	10	0.419	Very strong
Gender	Mode choice	x^2=121.369	0.000	2	0.318	Very strong
occupation	Mode choice	x^2=14.454	0.071	8	0.078	weak

4.6. Factors influencing mode choice behavior

This section of the study examines the mode choice behavior of commuters and the tendency to shift to public transport. Three main attributes of a trip, namely travel time, travel cost and comfort, were asked to be ranked by respondents according to their preference. Figure 10 shows the distribution of commuters between the attributes that influence their choice of mode for each mode. 80.50% of bicycle commuters and 51.75% of car commuters value time most, while 51.50% of public transport commuters value cost most. It has also been discussed above that income and mode choice have a very strong relationship with mode choice for these respondents.

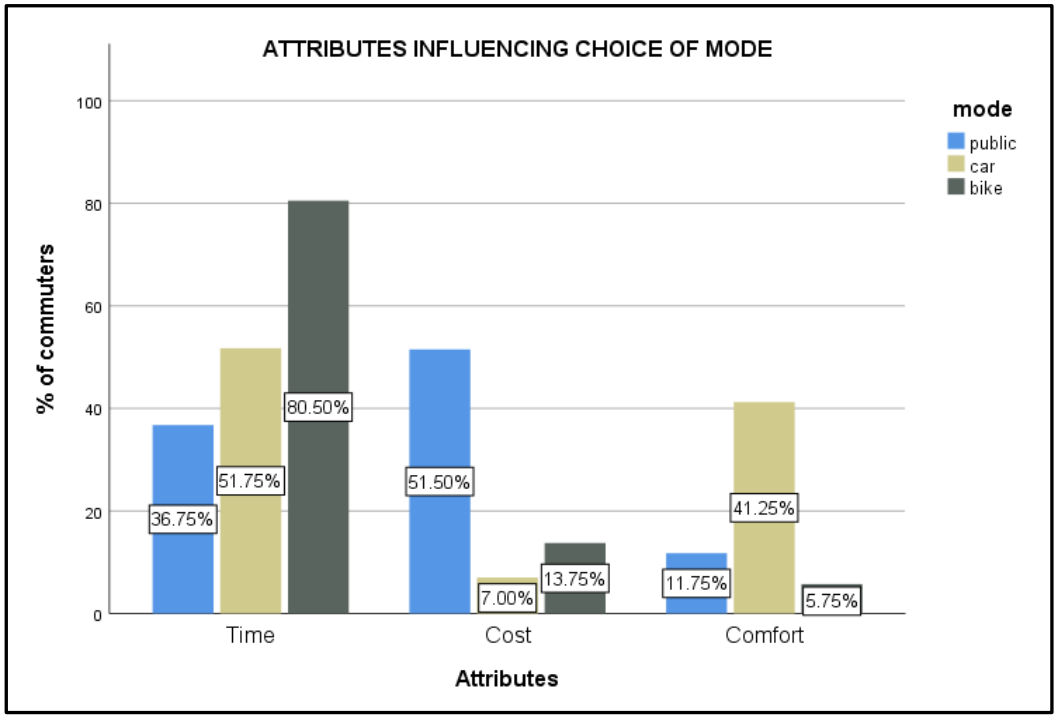


Fig. 10. Attributes influencing mode choice

After time, the most valued attribute is comfort, which is 41.25% for the car mode and cost, 13.75%, for the bicycle mode. The lower purchase price and fuel consumption make the motorcycle an economical mode of transportation ,and its small size makes it easier to maneuver in congestion, resulting in a shorter average journey time (Fadilah et al., 2022).

4.7. Reason behind not using public transportation

Karachi's poorly operated public transport system has forced commuters to shift to private transport, resulting in an unsustainable transport system. The existing PT is unable to meet

the increasing average travel demand (Ibad, 2020). This study shows people's behavior towards PT. Figure 11 clearly expresses the main deficiency of current PT. More than half of the respondents (bicycle=75.75%, car=50%) claim that PT is a less efficient system in terms of travel time. Since there is no enforcement of service level criteria (headways, punctuality, and seat/space availability) by the authorities, there are no bus schedules for any mode and route of PT in Karachi, and the entire PT is operated on the principle of profit maximization by its operators, resulting in an unreliable mode of transport (Ilyas and Garg, 2023). The data collected in this study indicate that car users have a more negative view of PT in terms of safety, while motorcycle users consider it less efficient in terms of time. These results are shown in Figure 11.

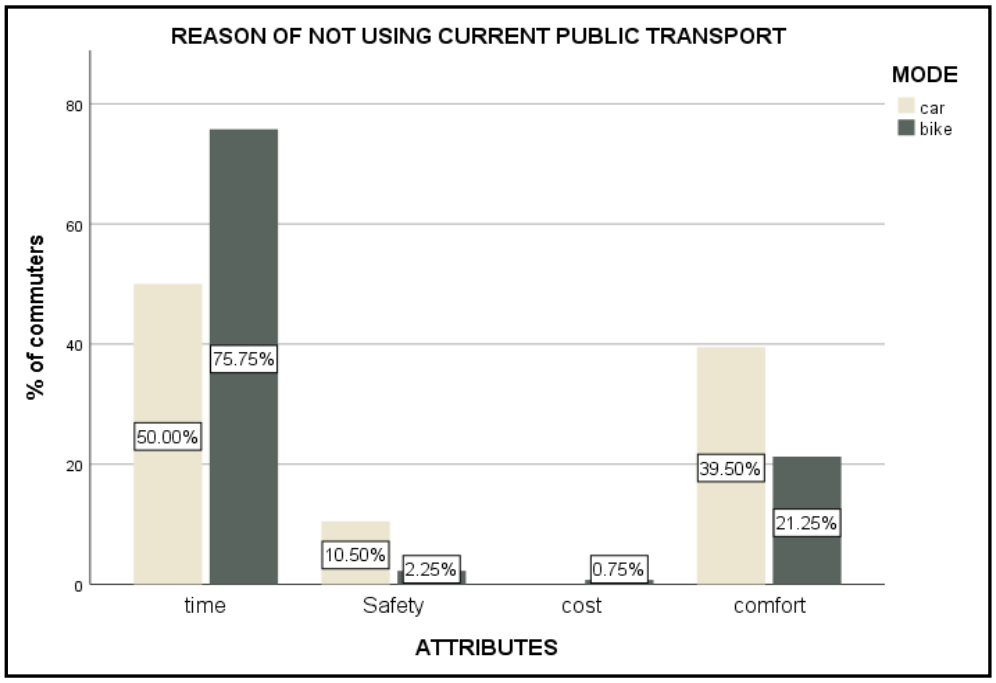


Fig. 11. Clustered bar graph of reasons behind not using current public transport with respect to car and bike mode

4.8. Private vehicle commuter's willingness to shift towards public transportation

During the survey, private car users were specifically asked if they would shift to public transport if the problem was solved. Figure 13 shows the decision of commuters to shift to public transport in relation to the problems reported by commuters.

The clustered bar graph in Figure 12 shows the willingness of people to shift to public transport if the stated problem is solved. An open-ended question was asked to private mode commuters about problems of public transport and the answers fall into 4 categories, i.e. safety, time, cost, comfort. All the people (100%) who claim that public transport is expensive are willing to switch if their concern is solved. In addition, it can be seen in Figure 12 that for each category of stated problem, more than 50% of people are willing to change if the problem is solved.

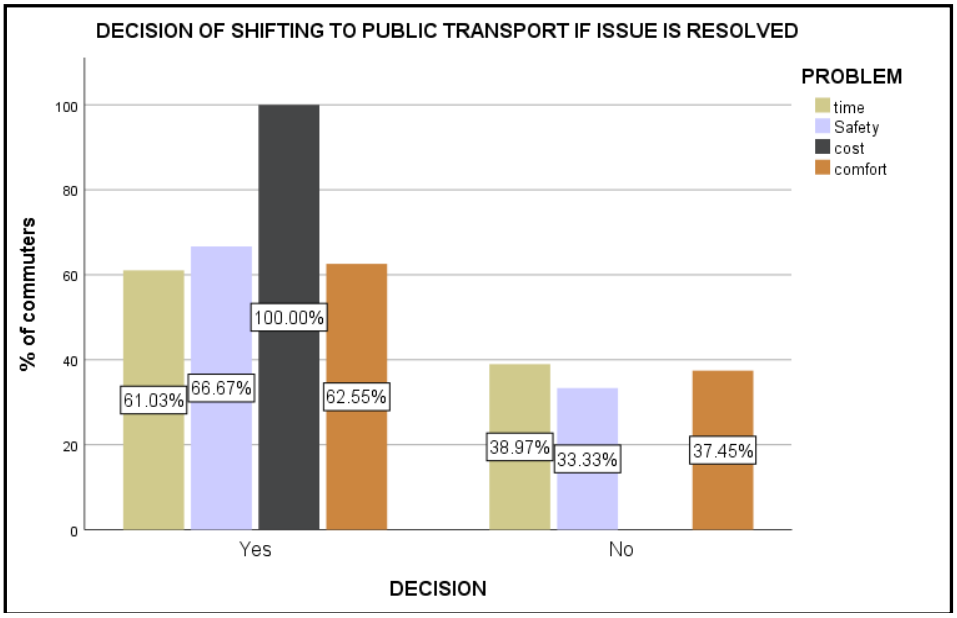


Fig. 12. Clustered bar graph of commuter's decisions of shifting towards public transport if the problem is resolved

4.9. Reason behind not using private mode

PT users were asked about the reasons for not using private mode. Descriptive answers were recorded which precisely fall into seven categories (safety, cost, not available, cannot drive, road condition, congestion, parking). Figure 13 shows the distribution of commuters among the reasons stated by commuters of public mode. It can be seen that more than 80% of commuters are those who do not own a private vehicle and somehow are compelled to rely on such unreliable public mode of transportation, which are referred to as Captive Riders in the literature (Fang et al., 2021).

5. DISCUSSION

The public transportation system in Karachi has evolved, mainly through the involvement of the informal sector, in an unplanned manner (Fatima et al., 2022). It is shown in this study that the most important problem for the current system is overcrowding of the system, which is handled by buses, minibuses and chinchis. The share of mode choice for the current PT system is around 17% on the studied arterials of Karachi. It is less than most metropolitan cities in the world (as shown in Table 1), including Mumbai and Dhaka whose geographic and demographic settings are similar to Karachi. Oeschgar et al. (2020) has shown that the share of PT in mode choice has been increasing in the metropolitan cities of the world. However, in the case of Karachi, comparison of the results of this study with a previous reported study by Siddiqui and Eren (2022) shows that the share of PT is decreasing in Karachi. It was reported as 40% in 2013, after which it has decreased to 16%, as per data collected in the present study. It also shows that the proportion of buses in vehicles' fleet of Karachi has not increased from 1% since 2011, it is the same proportion found in the data of the present study. This is indicative of the fact that PT has not expanded as per the expansion in population and travel demand in the city, resulting in insufficient capacity and consequent diversion of people to other modes.

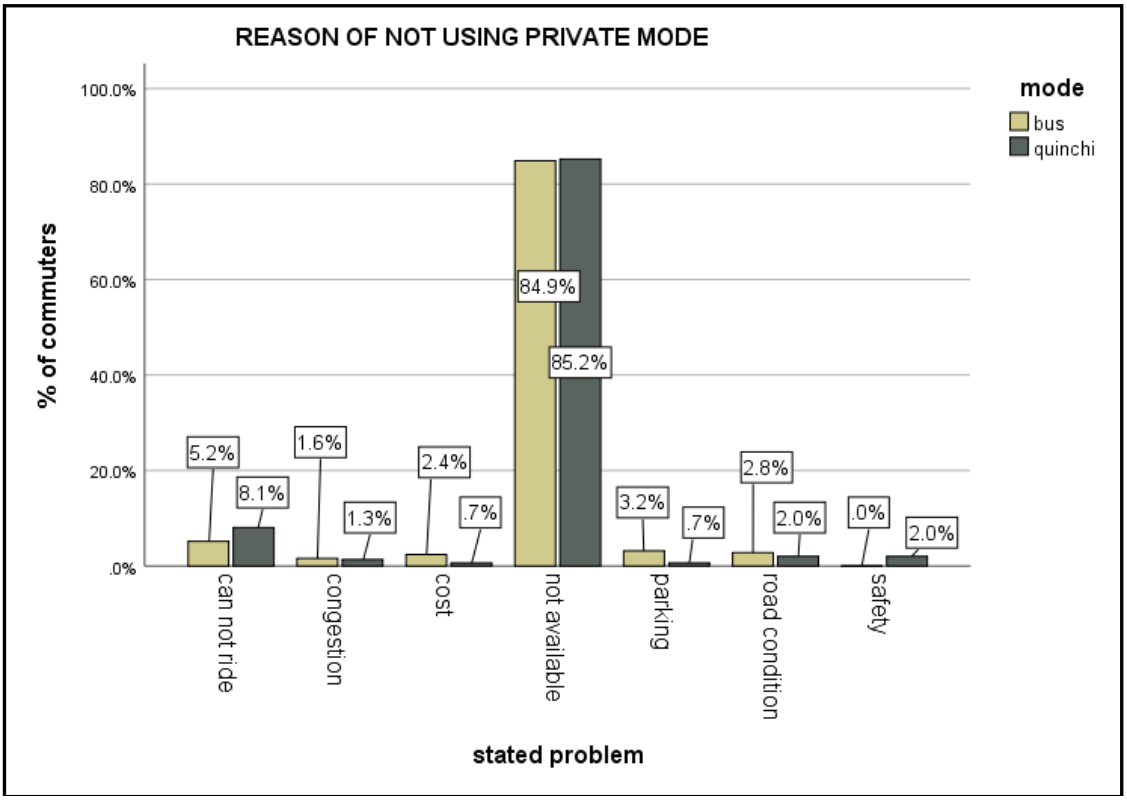


Fig. 13. Clustered bar graph of reasons stated by public mode commuters for not using private mode with respect to bus and quinchi users

Most PT riders belong to the captive riders who cannot afford their own vehicle. It is also reinforced by the fact that education and income have a strong correlation with mode choice, with higher education and income belonging to private transport users (Kashifi et al. 2022). Among these users, sustainable trends such as carpooling are not common, as evidenced by the low car occupancy rate. On the other hand, bicycles are usually occupied by an additional passenger. Car occupancy and mode choice show a lack of awareness of sustainable transport among road users, especially those with higher income, as they prefer to use private vehicles with low occupancy (more so for car users). In addition to economic and social background, gender also had a significant impact on mode choice, as confirmed by previous studies. This is a cultural aspect that has been found in other studies (Marvi et al., 2022) and that needs to be taken into account in future planning.

It seems that most of the private vehicle users consider PT to be a slow and uncomfortable service. Comfort can also be linked with the overcrowding of the current PT which has been identified as a low LOS measure by the respondents. Therefore, it seems likely that increasing the number of buses, especially on important routes, will increase the mode choice of PT in Karachi. This will reduce the headway between the buses and increase the capacity of the current system solving the main issues with the current PT system. In terms of promoting PT in Karachi, cost seems to be the most important element which is clearly favored by the private mode users. This issue is also highlighted by the fact that the current PT users are also those who belong to the lower income category and cannot afford their own vehicle.

6. CONCLUSION AND RECOMMENDATION

The objective of this study was to investigate the state of operation of different modes on major arterial roads in Karachi. An in-depth analysis of the mode choice behavior of travelers in Karachi was conducted and compared with other cities in the world. The findings of this study are used to suggest measures to increase the use of public transport and promote sustainable transport in this mega metropolitan city.

The results of the data analysis show that most of the PT users are captive users who cannot afford their own vehicles. Travelers belonging to high-income groups prefer to use private cars, and those who own bicycles are more likely to share their rides. In addition to income, mode choice has also been linked to education and gender, with male travelers and those with less education more likely to use PT. Current trends have shown that the share of cars has not increased in the last decade, while their share in the mode has decreased.

These findings indicate that the current PT is insufficient in capacity and lacks in providing comfortable means of transportation. This was also confirmed by the public opinion survey. It is expected that increasing the number of buses and reducing their headway may increase their ridership. The study also shows the preferential facilities needed for the female travelers who are culturally more inclined to use the PT. There is also a lack in the use of other sustainable approaches such as: walking and car sharing. Therefore, an awareness campaign to promote these modes should also be initiated. BRT metro service has been initiated on some corridors in Karachi. The results of this service on travel patterns are yet to be seen.

Reference

1. Abdel Wahed Ahmed M.M., N. Abd El Monem. 2020. “Sustainable and green transportation for better quality of life case study greater Cairo-Egypt”. *Hbrc Journal* 16(1): 17-37.
2. Abdullah M., N. Ali, M. A. Javid, C. Dias, T. Campisi. 2021. “Public transport versus solo travel mode choices during the COVID-19 pandemic: Self-reported evidence from a developing country”. *Transportation Engineering* 5: 100078.
3. Aguiléra A., J. Grébert. 2014. “Passenger transport mode share in cities: exploration of actual and future trends with a worldwide survey”. *International Journal of Automotive Technology and Management* 14(3-4): 203-216.
4. Anwar A., H. Leng, H. Ashraf, A. Haider. 2024. “Measuring the Transit-Oriented Development (TOD) levels of Pakistani megacities for TOD application: A case study of Lahore”. *Sustainability* 16(5): 2209.
5. Baak M., R. Koopman, H. Snoek, S. Klous. 2020. “A new correlation coefficient between categorical, ordinal and interval variables with Pearson characteristics”. *Computational Statistics & Data Analysis* 152: 107043.
6. Baqa M.F., F. Chen, L. Lu, S. Qureshi, A. Tariq, S. Wang, Q. Li. 2021. “Monitoring and modeling the patterns and trends of urban growth using urban sprawl matrix and CA-Markov model: A case study of Karachi, Pakistan”. *Land* 10(7): 700.
7. Böhler-Baedeker S., H. Hüging. 2012. *Urban transport and energy efficiency: module 5h. Sustainable transport: a sourcebook for policy-makers in developing cities*. GIZ. Zusammenarbeit, Bonn, Germany. BMZ Federal Ministry for Economic Cooperation and Development.

8. Brohi S., I.A. Memon, S. Kalwar, N. Sahito. 2021. "Predicting the use of public transportation service: The case study of karachi circular railway". *PalArch's Journal of Archaeology of Egypt/Egyptology* 18(3): 4736-4748.
9. Brugmann J. 2021. *Is there method in our measurement? The use of indicators in local sustainable development planning*. In: The Earthscan Reader in Sustainable Cities. P. 394-410. Routledge.
10. de Andrade J.B.S.O. 2016. "The adoption of strategies for sustainable cities: A comparative study between Newcastle and Florianópolis focused on urban mobility". *Journal of Cleaner Production* 113: 681-694.
11. Economics G. 2016. *Economic evidence base for London 2016*. Water Supply and Drainage. P. 295-296.
12. Fadilah S.R., H. Nishiuchi, A.M. Ngoc. 2022. "The impact of traffic information provision and prevailing policy on the route choice behavior of motorcycles based on the stated preference experiment: A preliminary study". *Sustainability* 14(23): 15713.
13. Fang D., Y. Xue, J. Cao, S. Sun. 2021. "Exploring satisfaction of choice and captive bus riders: An impact asymmetry analysis". *Transportation Research Part D: Transport and Environment* 93: 102798.
14. Fatima M., M.I. Khan, S.K.A. Naqvi. 2022. "Gauging the efficiency of public transport in Karachi: An application of Data Envelopment Analysis (DEA)". *Pakistan Journal of Social Research* 4(03): 607-616.
15. Guan J., C. Xu. 2018. "Are relocatees different from others? Relocatee's travel mode choice and travel equity analysis in large-scale residential areas on the periphery of megacity Shanghai, China". *Transportation Research Part A: Policy and Practice* 111: 162-173.
16. Guzman L.A., S.G. Cardona. 2021. "Density-oriented public transport corridors: Decoding their influence on BRT ridership at station-level and time-slot in Bogotá". *Cities* 110: 103071.
17. Ha J., S. Lee, J. Ko. 2020. "Unraveling the impact of travel time, cost, and transit burdens on commute mode choice for different income and age groups". *Transportation Research Part A: Policy and Practice* 141: 147-166.
18. Haghshenas H., M. Vaziri. 2012. "Urban sustainable transportation indicators for global comparison". *Ecological Indicators* 15(1): 115-121.
19. Heraa N. 2013. *Transportation system of Karachi, Pakistan*. PhD diss., Faculty of the Graduate School of Asia Pacific Studies, Ritsumeikan Asia Pacific University. 2013.
20. Hidalgo D., C. Huizenga. 2013. "Implementation of sustainable urban transport in Latin America". *Research in Transportation Economics* 40(1): 66-77.
21. Ibad M. 2020. "Public transport in Karachi: A study of relationship between consumer perception and use of private vehicles". *International Journal of Social, Political and Economic Research* 7(1): 36-55.
22. Ilyas F., M. Garg. 2023. "Beyond safety: Gendered mobility in Karachi and Delhi". *Anthropology Now* 15(1): 54-68.
23. Journeault M., A. Perron, L. Vallières. 2021. "The collaborative roles of stakeholders in supporting the adoption of sustainability in SMEs". *Journal of Environmental Management* 287: 112349.
24. Kashifi M.T., A. Jamal, M.S. Kashefi, M. Almoshaogeh, S.M. Rahman. 2022. "Predicting the travel mode choice with interpretable machine learning techniques: A comparative study". *Travel Behaviour and Society* 29: 279-296.

25. Khan U.R., J.A. Razzak, R. Jooma, M.G. Wärnberg. 2022. „Association of age and severe injury in young motorcycle riders: A cross-sectional study from Karachi, Pakistan". *Injury* 53(9): 3019-3024.
26. Khanna P., S. Jain, P. Sharma, S. Mishra. 2011. "Impact of increasing mass transit share on energy use and emissions from transport sector for National Capital Territory of Delhi". *Transportation Research Part D: Transport and Environment* 16(1):65-72.
27. Kiran A., D.S. Qadri. 2021. "On the wrong side of the track: the role of Karachi Circular Railway in determining intra-city boundaries". *CBER Conference*. Available at: https://ir.iba.edu.pk/esdcber/2021/day3/13.
28. KMTC. 2012. *Karachi mass transit program investment opportunities*. Pakistan.
29. Lau J.C.Y. 2013. "Sustainable urban transport planning and the commuting patterns of poor workers in a historic inner city in Guangzhou, China". *Habitat International* 39: 119-127.
30. Marvi H., M. Soomro, I.A. Memon. 2022. "Influence of socio-economic factors on mode choice of employees in Karachi City". *Global Economics Review* 7(2): 13.
31. Mehdi M.R., et al. 2011. "Spatio-temporal patterns of road traffic noise pollution in Karachi, Pakistan". *Environment International* 37(1): 97-104.
32. Moro E., D. Calacci, X., Dong, A., Pentland. 2021. "Mobility patterns are associated with experienced income segregation in large US cities". *Nature Communications* 12(1): 4633.
33. Nakshi P., A.K. Debnath. 2021. "Impact of built environment on mode choice to major destinations in Dhaka". *Transportation Research Record* 2675(4):281-296.
34. Neirotti P. 2014. "Current trends in Smart City initiatives: Some stylised facts". *Cities* 38: 25-36.
35. Prassas E.S., P.R. Roess. 2020. *The highway capacity manual: A conceptual and research history.* Volume 2. Cham, Switzerland: Springer International Publishing.
36. Raza M. 2016. *Exploring Karachi's transport system problems: A diversity of stakeholder perspectives*. International Institute for Environment and Development.
37. Richardson B.C. 2005. "Sustainable transport: Analysis frameworks". *Journal of Transport Geography* 13(1): 29-39.
38. Russo F. 2022. "Sustainable Mobility as a Service: Dynamic models for agenda 2030 policies". *Information* 13(8): 355.
39. Shah M.H., I.A. Memon, A.H. Talpur, W.A. Sethar, G. Das. 2021. "Factors influencing private transport users to shift towards public transport In Karachi". *Engineering Science and Technology International Research Journal (ESTIRJ)* 5(1): 61-66.
40. Siddiqui S., Ş.G. Eren, 2022. "The analysis of the sustainability pillars of Karachi city's transportation system". *Journal of Architectural Sciences and Applications* 7: 181-190.
41. Soomro R., I.A. Memon, A.F.H. Pathan, W.A. Mahar, N. Sahito, Z.A. Lashari. 2022. "Factors that influence travelers' willingness to adopt bus rapid transit (Green Line) service in Karachi". *Sustainability* 14(16): 10184.
42. Todd L.S.T. 2013. *TDM. Online TDM Encyclopedia [Text]/Litman Todd*. Victoria Transport Policy Institute.
43. UN Declaration. 1972. *Declaration of the United Nations conference on the human environment*. Available at: http://www. unep. org/Documents. Multilingual/Default.asp.
44. UN. 2018. *68% of the world population projected to live in urban areas by 2030*. Available at: https://www.un.org/development/desa/en/news/population/2018-revision-of-world-urbanization-prospects.html.
45. Valdes C., A. Monzon, F.G. Benitez. 2016. "Sustainable urban transportation strategies: Searching for synergies". *KSCE Journal of Civil Engineering* 20: 1066-1075.

46. Zhang X., X. Kong, R. Yan, Y. Liu, P. Xia, X. Sun, H. Li. 2023. “Data-driven cooling, heating and electrical load prediction for building integrated with electric vehicles considering occupant travel behavior”. *Energy* 264: 126274.

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