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Transportation Research Procedia 00 (2018) 000–000

Transportation Research Procedia

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World Conference on Transport Research - WCTR 2019 Mumbai 26-31 May 2019

Modelling induced travel demand in a developing country: evidence from Dhaka, Bangladesh

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Abstract

This research evaluates induced travel demand with the construction of transport infrastructure, using flyovers as a case study. Induced travel demand is defined as an increase in travel as a result of any increase in the capacity of a transportation system. However, relatively little is known about the induced travel demand effects of flyover infrastructure in developing countries.

This research endeavours to answer the question of whether the construction of flyover induces travel kilometers or induced trips. The objectives of this research are: to estimate average travel distance and trip frequencies based on socio-economic and travel characteristics of flyover and non-flyover users; to measure induced travel kilometres and induced trips caused by construction of flyovers; and to model induced travel kilometres and induced trips. Using purposive sampling techniques, both an intercept survey and online questionnaire were conducted to collect the data from 1060 vehicle users who used flyover and non-flyover roads in Dhaka.

An independent samples t-test estimated that there is a statistically significant difference between flyover and non-flyover users. Induced travel kilometres and induced trips made by these two groups are also reported. Using a linear multiple regression model, the study found that the number of trip frequency of flyover users is increased by 0.350 owing to a one minute savings in their travel time. The findings of this research contribute to guide policies that include the effects of induced travel demand when constructing new roadway facilities, particularly in Dhaka and other cities in developing countries.

Keywords: transport infrastructure, induced travel demand, area-based studies, facility-specific studies, behavioral responses, flyover

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1. Introduction

This research evaluates induced travel demand with the construction of transport infrastructure. Transport policy initiatives have centred on the modelling of traffic growth and consequent capacity expansion (construction of new roads, highways, bridges, addition of new lanes) to accommodate such growth (Su, 2011). Flyovers are an important component of transport infrastructure, and are constructed at busy intersections or along the highways in order to facilitate the uninterrupted movement of traffic. The intended purpose of flyover construction is to reduce congestion in urban areas (Auttakorn, 2013; Mathew, 2012). Policy supporting flyover construction is often justified on the grounds that the capacity expansions provide benefits through ‘travel time savings’. The arguments put forward are that a reduced travel time enhances accessibility to goods and services, creates economies of scale, increases property values and facilitates the opening of new opportunities (companies, retail shops or other) along a capacity expanded corridor (Lakshmanan and Chatterjee, 2005; Mejía Dorantes et al., 2010). However, based on empirical evidence, researchers have questioned the purported benefits of adding or expanding roads (Fulton et al., 2000; Litman, 2005; Özuysal and Tanyel, 2008). These studies have shown that the benefits are often overstated due to the omission of ‘induced demand’ effects in the modelling of traffic growth.

Induced travel demand is the additional travel that results from road improvement (Goodwin and Noland, 2003; Litman, 2001). The improvement of a road or the addition of a new road to the existing network can induce extra traffic due to travel time savings or increased travel speeds (Hills, 1996; Hymel et al., 2010). Investment in new roads or upgrading existing ones induces more traffic is not a new phenomenon (Liyanage, 2009; UN, 2006). The presence of induced travel demand can be explained by the micro-economics theory of supply and demand (Coombe, 1996; Ewing and Lichtenstein, 2002; Fulton et al., 2000; González-Marrero and Marrero, 2011; Yao et al., 2003; Zhao and He, 2011). It occurs due to the decrease in the cost of a trip, especially the travel time and as a consequence, an increase in the distance travelled (González and Marrero, 2012). Based on the micro-economics of supply and demand, any increase in supply (roadway capacity), results in a reduction in price (the cost of travel), which leads to an increase in travel demand (Behrens and Kane, 2004).

In the short-run, increased roadway capacity reduces travel time (DeCorla-Souza and Cohen, 1999). The new roadway facilities relieve traffic congestion and increase travel speed, which generally contributes to induced traffic (Cervero and Hansen, 2000; Goodwin, 1996). As travel speed increases people tend to choose more distant destinations and drive more kilometres (Litman, 2005). People usually choose the new road over the old one due to less travel time and improved safety (Shengchuan et al., 2012). In addition, building new roads or expanding existing ones spurs new traffic and diverts travel from other routes (Hills, 1996; Scott, 2002). People change their destination due to travel time savings for capacity expansion of existing roads (Mokhtarian et al., 2002). In the long-run, roadway improvement may pave the way for sprawl development, discourage transit use and induce auto-oriented development in reducing traffic congestion (Cervero and Hansen, 2000; Hansen and Huang, 1997). Roadway capacity improvement leads to an increase in automobiles in the long-run (Kang et al., 2009b; Kitamura, 2009).

Induced traffic can also occur for a variety of behavioral mechanisms including mode shift, route shift, redistribution of trips, generation of new trips and changes in land use (Noland, 2001). In the short-run, behavioral responses include route switches, mode switches, a change in travel departure time, and a change in destination. But in the long-run, they include job and residential relocations and changes in land use (Ewing and Lichtenstein, 2002; Hymel et al., 2010; Kang et al., 2009a; Noland, 2001; Noland and Cowart, 2000; Yao et al., 2003).

Researchers have measured induced travel demand in developed and developing countries over the years. Two types of induced travel demand studies exist: area-based studies and facility-specific studies. In the area-based studies, induced demand is examined at the region, county and metropolitan level (Cervero and Hansen, 2002; González and Marrero, 2012; He and Zhao, 2013; Hymel et al., 2010; Shengchuan et al., 2012; Zhao and He, 2011). In the facility-specific studies, induced travel demand is examined at the project level such as highway, motorway, tunnel, and expressway (Mewton, 2005; Mokhtarian et al., 2002; Özuysal and Tanyel, 2008; Parthasarathi et al., 2003; Rohr et al., 2012; Zeibots, 2003). These studies have used aggregate datasets rather than aggregate datasets to measure induced travel demand. However, disaggregate analyses enjoy inherent advantages over aggregate analyses in studying travel behaviour, including induced demand (Parthasarathi, 2001). To date, only a few studies have attempted to use disaggregate travel data to derive induced demand (Fröhlich, 2003; Parthasarathi et al., 2003). These disaggregate studies once again focused on geographical areas rather than specific facilities.

Facility-specific induced demand studies have focused on different types of facilities, however, relatively little is known about the induced demand effects of transport infrastructure expansion, especially in developing countries (Kweronda, 2013; Loiwal, 2007). Therefore, this research examines whether the construction of flyover induces travel kilometers or induced trips. The objectives of this research are: 1) to estimate average travel distance and trip frequencies based on socio-economic and travel characteristics of flyover and non-flyover users; 2) to measure induced travel kilometres and induced trips caused by construction of flyovers; and 3) to model induced travel kilometres and induced trips. The findings from this research are important to guide policies to include the effects of induced travel demand when constructing new transport infrastructure, such as flyovers in developing countries. Induced travel demand needs to be integrated into traffic forecasting so as to take into account total congestion figures.

This paper is organized as follows: Section 2 provides a detailed discussion of material and methods; Section 3 the results of the analysis, including average travel time and distance, average trip frequency, factors affecting travel distance and frequency, and modelling induced travel kilometres and induced trips; Section 4 provides a discussion, followed by the conclusion in Section 5.

2. Materials and methods

2.1 Study area

This research captures induced travel demand impacts of transport infrastructure using flyovers as a case study in Dhaka, Bangladesh. Dhaka is one of the largest mega cities in the world (Habib et al., 2005; UN, 2006) with a current population of 15 million according to the last population census made by the Government of Bangladesh (BBS, 2011). The city is struggling to cope with this population pressure in terms of providing effective public transport services (Niger, 2013). Unlike other mega cities, where trains play an essential part of facilitating everyday travel (Kenworthy, 2003), this mode of transport serves little ease of travel for intra city travel in Dhaka (Habib, 2002). Although there are waterways surrounding the city, there is no water-based transport systems for city dwellers. In addition, these waterways are not properly linked to the road transport network (Shajahan and Nilufar, 2013). The major roads are blocked by vehicles in peak hour. As the road supply is insufficient compared to demand, the city experiences a loss of around US$ 2,444 million per year owing to traffic congestion and road accidents (Siddique et al., 2013). Recently, the Government of Bangladesh has constructed flyovers in order to reduce traffic congestion and increase access to new neighborhoods. However, these initiatives do not reduce traffic congestion.

2.2 Data

Five flyovers are currently operating in Dhaka, and were selected as cases in order to investigate the induced travel behavior. A control road of non-flyover users was also used to compare the induced travel behavior between flyover and non-flyover users. An intercept survey and online questionnaire were conducted to collect the required data. Using a purposive sampling technique, the data was collected from 1085 individuals, and after reviewing the responses, 1060 individual responses were considered for further analysis. Individual responses were taken from vehicle users (buses, private cars, CNG powered three-wheelers, and motor cycles) who used the flyovers and non-flyover roads at a proportionate rate based on the modal split in Dhaka. The intercept survey was undertaken at bus stations, railways stations, Compress Natural Gas (CNG) stations, airports, shopping centers, commercial areas, recreational areas, and hospitals. This survey was conducted at the entry and exit points of these locations, as the respondents entered and left. Responses were recorded through face-to-face interviews with the respondents. This survey was conducted during daylight, between 9AM and 6PM from September 2015 to January, 2016.

2.3 Outcome variables

Change in travel distance was used as an outcome variable to measure induced travel kilometres. Respondents were asked to indicate their trip origin, destination, and travel route before and after the construction of flyovers. Following this, change in travel distance was transformed by subtracting the past travel distance from the current travel distance. This variable was a continuous variable, and was normally distributed. Change in trip frequency was also used as an outcome variable to determine the induced trips. Respondents were asked to indicate the amount of their past and present trip frequencies. Change in trip frequency was then formulated by subtracting the past trip frequency from the present trip frequency; this variable was also a continuous variable.

2.4 Explanatory variables

Previous studies have shown that different factors (travel time, travel cost, travel speed, age, gender, income, car ownership, trip purposes, level of traffic congestion, residential location, and job location) influence an individual's travel distance and trip frequency (Ellder et al., 2014; González-Marrero and Marrero, 2011; Kuzović et al., 2010; Sperry et al., 2012). Among these factors, travel time, age, gender, income, car ownership, and trip purposes were examined to investigate the induced travel kilometres and induced trips of flyover and non-flyover users. Four new factors: education, occupation, household size and home ownership were also examined.

The variables regarding the socio-economic and travel characteristics of the respondents were nominal categories. The data regarding age was originally stored into five categories (0-14, 15-29, 30-44, 45-59, and 60 or above). These categories were recoded into four categories because there were no responses from respondents for the 0-14 classification. The data on gender (male and female), occupation (working and student), home ownership (own a flat/house and rented), and car ownership (yes and no) were collected into two categories. The variable of income was stored into five categories (low income, lower middle income, middle income, higher middle income, and higher income) and household size into six (1, 2, 3, 4, 5, and 5+). Respondent's education level data was collected into five categories (no formal schooling, primary school, secondary school, diploma/certificate course, and higher degree). The first category was merged with the second category due to a very low response rate. The trip purpose related data was collected into seven categories (work, education, shopping, recreation, family visit, medical, and others. However, the latter two categories were excluded in the analysis because there was no response rate in these categories. The data regarding change in travel distance and travel time were collected as discrete variables however these variables were transformed into categorical variables. The change in travel distance was transformed into three categories: no change, increased travel distance and decreased travel distance. Change in travel time was also categorized into three categories: no change, increased travel time and decreased travel time. The reasons for the classification of these variables was to determine whether the construction of flyovers generate induced travel kilometres and induced trips of individuals for either increased travel distance and time, or for decreased travel distance and time. Each category of the variables was tested by creating a separate dummy variable in the model. Finally, only the significant categorical variables were used in the analytical model to determine induced travel kilometres and induced trips.

2.5 Analytical method

An independent samples t-test was conducted to compare the difference-in-difference between flyover and non-flyover users using SPSS. A case-control variable was created whether individual using flyovers was coded as 1 and non-flyover users were coded as 0. Changes in travel distance and trip frequency were used as testing variable and case-control variable was used as grouping variable in the independent t-test model. A univariate linear model was separately conducted using the similar variables to determine the effect size (eta squared). Linear multiple regression was also used to identify the casual relationship among changes in travel distance, changes in trip frequency, and socio-economic characteristics of flyover and non-flyover users. This regression model is suitable for continuous outcome variables. The model has been widely used by researchers to measure the travel distance (Corpuz et al., 2006; Yawar, 2016) and trip frequency (Dodeen, 2014; Zenina and Borisov, 2013) of individual trip makers. This research was followed the similar approach to measure induced travel kilometres and induced trips of flyover and non-flyover users. This model identified the most statistically significant variables that influence induced travel kilometres and induced trips of flyover and non-flyover users.

3. Results

3.1 Average travel time and distance between flyover and non-flyover users

The average travel time of flyover users was 50.63 minutes. The average travel time of non-flyover users was 57.08 minutes. On the other hand, the average travel distance of flyover users was 11.88 km and the average travel distance of non-flyover users was 9.01 km.

3.2. Factors affecting travel distance between flyover and non-flyover users

3.2.1 Age

The highest average distance (14.04 kilometres) was travelled by flyover users with an age range of 60 years or above (5.5%), and the lowest average distance travelled by flyover users with an age range of 15-29 was 11.49 kilometres. Non-flyover users with an age range of 60 or above travelled a maximum distance (14.63 kilometres) for their regular trip purpose compared to others. The lowest average distance (7.81 kilometres) travelled by non-flyover users was in the 30-44 age range (Fig. 1).

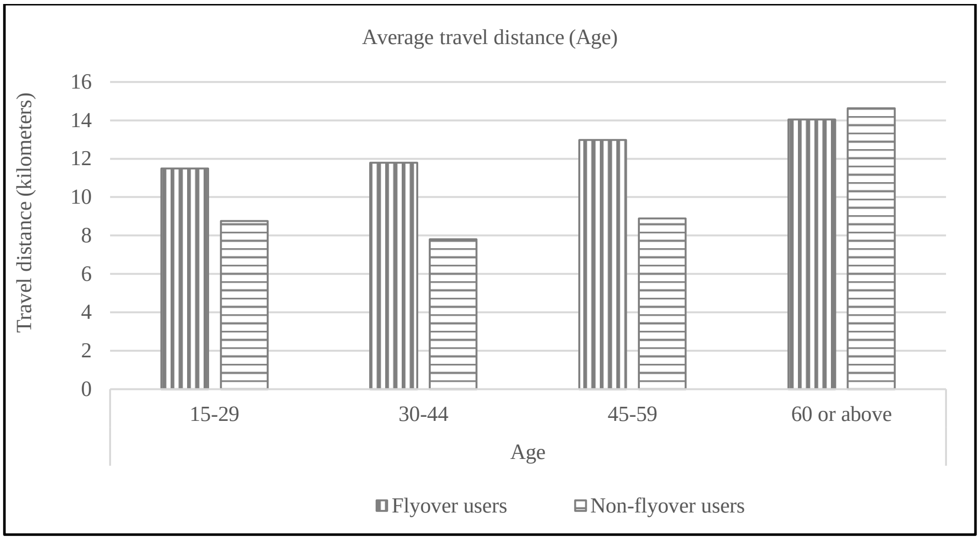

Fig. 1. Average travel distance of flyover and non-flyovers users based on age.

Flyover users (10.52%) with an age range of 15-29 travelled from one to nine kilometres more compared to travel distance before construction of flyovers. Flyover users (2.80%) with an age range of 30-44 travelled from one to five kilometres. 2.22% and 3.03% flyover users with an age range of 45-59 and 60 or above travelled four kilometres further for their regular trip purposes, respectively. There was no change in travel distance of non-flyover users. Therefore, they did not generate any induced travel kilometres after the construction of flyovers.

3.2.2 Gender and occupation

The average distance travelled by flyover users also varied with gender. The average travel distance of males (12.55 kilometres) was higher than females (11.13 kilometres). A similar result was found in relation to the occupation of flyover users. The average distance travelled by working flyover users (71.9%) was 12.05 kilometres, whereas the average distance travelled by students (28.1%) was 11.45 kilometres. Male non-flyover users (10.15 kilometres) travelled more distance than females (7.83 kilometres). Working non-flyover users (65.7%) travelled 9.35 kilometres, whereas students (34.3%) travelled 8.35 kilometres (Fig. 2).

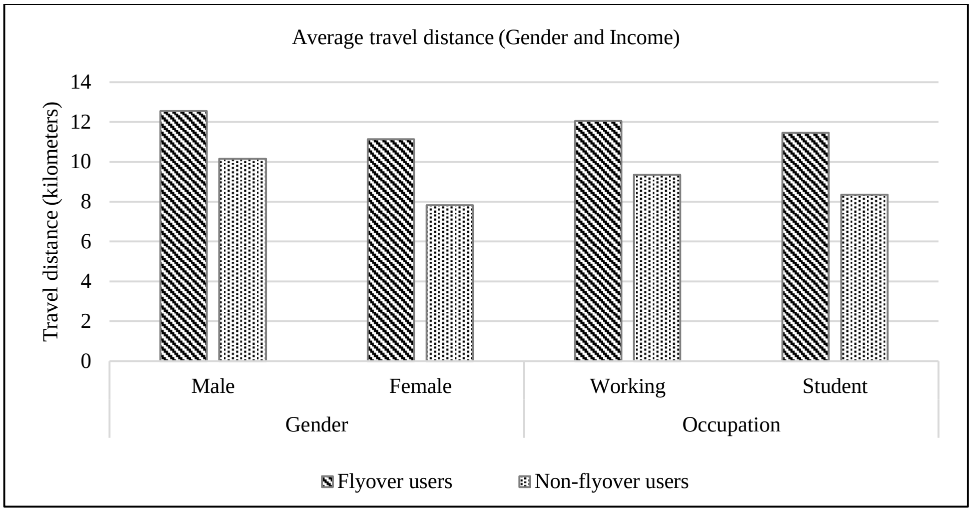

Fig. 2. Average travel distance of flyover and non-flyover users based on gender and occupation.

Male flyover users (5.49%) travelled from one to nine kilometres and female flyover users (13.77%) travelled one to seven kilometres further after the construction of flyovers. Working flyover users (5.74%) travelled from one to five kilometres and students (19.19%) travelled from one to nine kilometres more after the construction of flyovers.

3.2.3 Income

Higher income flyover users (15.6%) travelled greater average distances (14.19 kilometres) compared to other income groups. The lowest average distance (9.29 kilometres) was travelled by lower middle income flyover users (7%). Lower middle income non-flyover users (5.7%) travelled more distance (11.75 kilometres) than other income groups (Fig. 3). Lower income non-flyover users (27.1%) travelled the lowest average distance (7.29 kilometres).

Low income flyover users (23.17%) travelled more distance from one to nine kilometres. Middle income (2.33%) and higher middle income (8.66%) flyover users travelled one to five kilometres more, and higher income flyover users (6.90%) travelled one to four kilometres further after the construction of flyovers. No induced travel kilometres were generated by lower middle income flyover users.

3.2.4 Education

Flyover users, who had a higher university degree (71.8%) travelled a greater average distance (12.12 kilometres) compared to other groups (Fig. 3). The lowest average distance (8.98 km) was travelled by the flyover users, who had a primary school education (3.1%). Around 3% of non-flyover users with a primary school education travelled more distance (15.63 kilometres) compared to other groups. Non-flyover users (78.6%) who had a higher university degree education travelled the lowest average distance (8.59 kilometres).

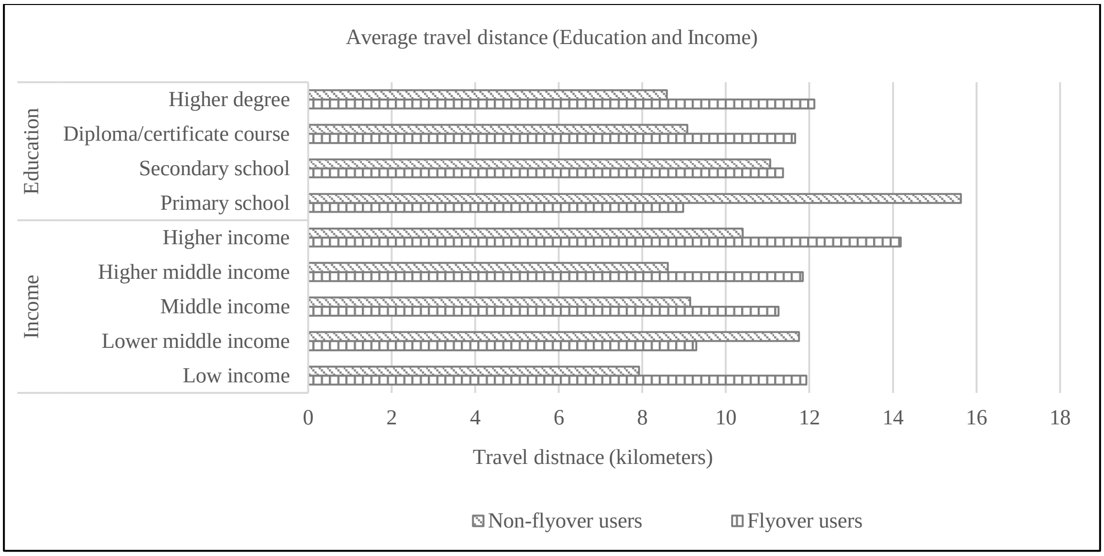

Fig. 3. Average travel distance of flyover and non-flyover users based on income and education.

No induced travel kilometres were generated by the flyover users who had primary school and secondary school education. Flyover users (5.13%) with a diploma degree travelled more from one to four kilometres. Flyover users (10.85%) with a higher university degree travelled from one to nine kilometres further compared to travel distance before construction of flyovers.

3.2.5 Home ownership, household size, and car ownership

Flyover users who owned a house (34.3%) travelled a greater average distance (13.26 kilometres) compared to those who did not own a house (11.15 kilometres) (Fig. 4). Flyover users with five family members (20.1%) travelled a greater average distance (14.11 kilometres) compared to other household sizes. The lowest average distance (10.94 kilometres) was travelled by the flyover users (3.4%), who lived alone. The average travel distance was higher among flyover users (25.6%), who had a car (12.30 kilometres) compared to those (74.4%), without a car (11.46 kilometres).

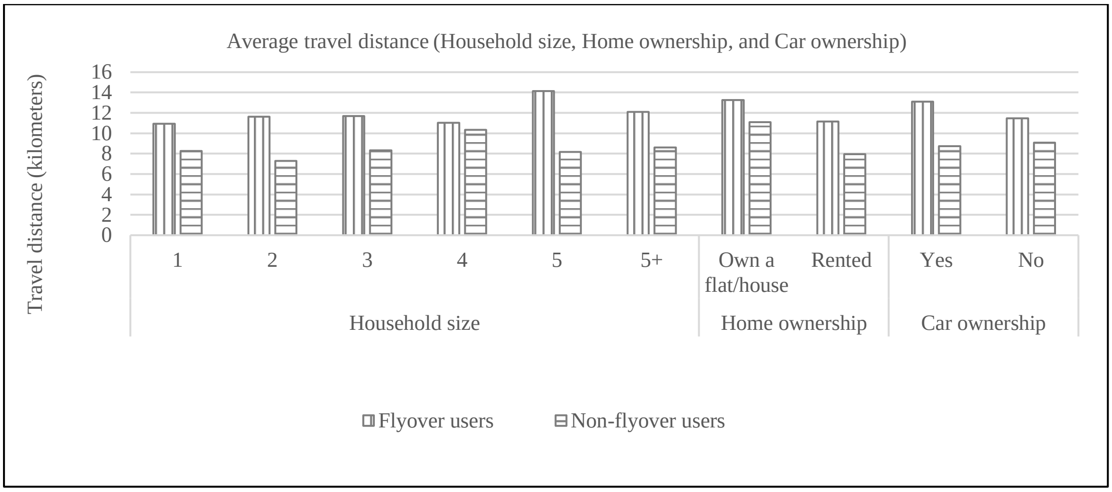

Fig. 4. Average travel distance of flyover and non-flyover users based on household size, home ownership and car ownership.

Non-flyover users who owned a house (33.8%) travelled 11.09 kilometres and non-flyover users who did not own a house travelled 7.95 kilometres. Non-flyover users with four family members (36.9%) travelled more distance (10.34 kilometres) compared to other household sizes. Non-flyover users who lived alone (9.1%) travelled an average of 8.25

kilometres and with two family members travelled the lowest average distance, (7.27 kilometres). Non-flyover users (76.7%) who did not own a car travelled more kilometres (9.09 kilometres) compared to those (23.3%) who did own a car (8.74 kilometres).

Flyover users (7.47%) who lived in their own house travelled from one to four kilometres, whereas flyover users (9.85%) who lived in a rented house travelled one to nine kilometres further after the construction of flyovers. Flyover users who lived alone and also a household of more than five did not generate induced travel kilometres. Induced travel kilometres generated by flyover users with a household size of four (9.21%) travelled from one to nine, and flyover users with a household size of five (12.94%) travelled from one to six kilometres further compared to travel distance before the construction of flyovers. Flyover users who owned a car travelled from one to four kilometres and flyover users who did not own a car travelled from one to nine kilometres further.

3.2.6 Trip purposes

The highest average distance of flyover users (7.4%) travelling for family visit purposes was 16.37 kilometres. The lowest average distance (8.91 kilometres) travelled by the flyover users (4.6%) was for recreational purposes. More non-flyover users (58.6%) travelled 8.60 kilometres for work, whereas 28.5% travelled 8.53 kilometres for educational purposes. Only 2.5 % of non-flyover users travelled 6.83 kilometres for recreational purposes.

Flyover users (6.22%) travelling for work reasons travelled from one to five kilometres and flyover users (23.07%) travelling for educational purposes travelled from one to nine kilometres further after the construction of flyovers. Flyover users travelling to shopping areas and for recreational purposes did not generate induced travel kilometres (Fig. 5).

3.2.7 Changes in travel time

Flyover users (5.2%) whose travel time increased travelled a greater average distance (18.35 kilometres). The lowest average distance (11.18 kilometres) was travelled by the flyover users (86.2%), whose travel time decreased. Non-flyover users (8.2%), whose travel time did not change travelled an average of 8.42 kilometres, while non-flyover users (86.2%), whose travel time increased, travelled an average of 9.10 kilometres. Flyover users (8.83%) whose travel time decreased generated induced travel kilometres from one to nine kilometres, and flyover users (4.34%) whose travel time increased travelled two kilometres further after the construction of flyovers (Fig. 5).

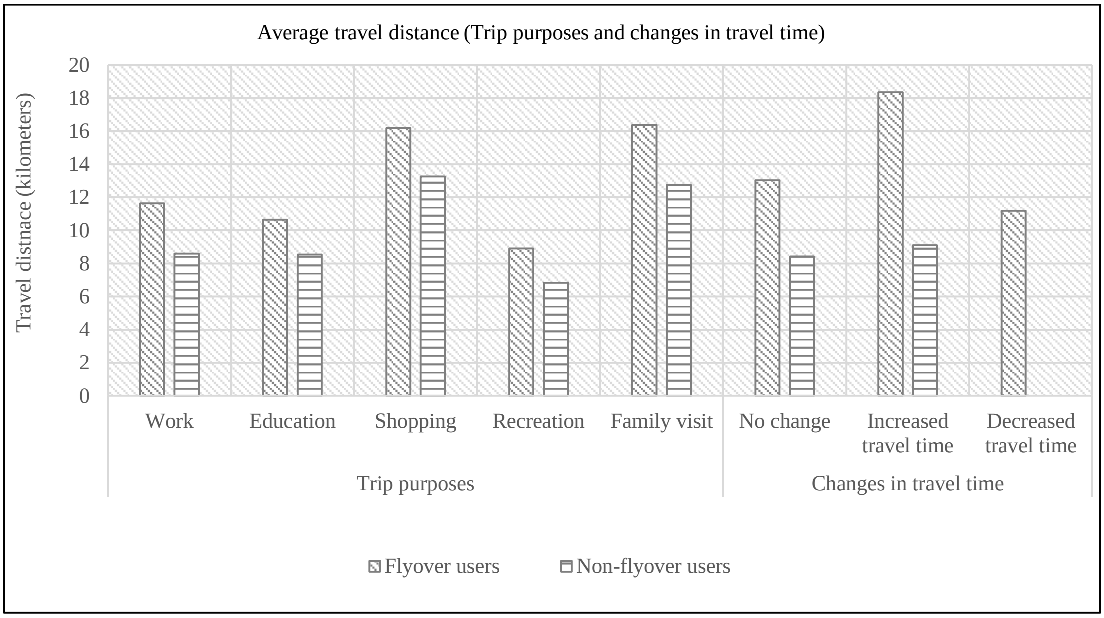

Fig. 5. Average travel distance of flyover and non-flyover users based on trip purposes and changes in travel time.

None of the non-flyover users changed their trip origin and destination for regular trip purposes. As there was no change in travel distance, the relationship between changes in travel distance and induced travel kilometres was excluded from the analysis.

3.3 Modelling induced travel kilometres of flyover users

An independent samples t-test was conducted to compare the distance travelled by flyover and non-flyover users. There was a significant difference in travel distance between the two groups, t (729) = 4.91, p <0.00, two-tailed with flyover users (M = 11.88, SD = 6.26) travel more kilometer than non-flyover users (M = 9.01, SD = 6.37). The magnitude of the differences in the means (mean differences = 2.87, 95% CI: 1.72 to 4.01). The flyover has small effect (Cohen's d = 0.36, eta squared = 0.03).

Before conducting the linear multiple regression analysis, the Pearson correlation analysis and variable inflation factors (VIF) were conducted to measure the strength of association and multicollinearity among the explanatory variables. There was a weak association amongst the explanatory variables and none of the explanatory variables had a VIF greater than 2 (Table 1 and 2).

Table 1. Correlation co-efficients among explanatory variables.

	Decreased travel time (minutes)	Trip purpose (education)	Trip purpose (recreation)	Car ownership
Decreased travel time (minutes)	-	.038	.069	-.037
Trip purpose (education)		-	-.119[a]	.022
Trip purposes (recreation)			-	-.082[b]
Car ownership				-

Note: 'a' and 'b' indicates Pearson correlation is significant at the 0.01 and 0.05 level (2-tailed) respectively.

Table 2. Multicollinearity statistics of explanatory variables.

Explanatory variables	VIF
Decreased travel time (minutes)	1.008
Trip purpose (education)	1.017
Trip purpose (recreation)	1.028
Car ownership	1.016

The model predicted that no induced travel kilometres were generated due to travel time savings (Table 3). The model also predicted that the change in travel distance decreased by 0.929 due to a one minute savings in travel time. Moreover, if the flyover users travelling for education purposes was increased by one unit, the change in travel distance also increased by 0.763 units. However, the model predicted that if flyover users who were travelling for recreation purposes were increased by one unit, the change in travel distance decreased by 1.964 units. In addition, the model predicted that if car ownership of flyover users was increased by one unit, the change in travel distance decreased by 0.663 units. The R Square shows that the model related to the changes in trip frequency of individuals explained 7% of the variance in the data. The model was also statistically significant (P<0.05) and the data suitably fit the model.

Table 3. Multiple linear regression model parameter estimates for flyover users.

Explanatory variables	B	Std. Error	t	Significance
Decreased travel time (minutes)	-.929	.361	-2.570	.011[b]
Trip purpose (education)	.763	.332	2.298	.022[b]
Trip purposes (recreation)	-1.964	.552	-3.556	.000[a]
Car ownership	-.663	.277	-2.398	.017[b]

Note: a and b indicates the regression co-efficient is significant at the 0.01 and 0.05 level

Table 4. Descriptive statistics of the significant explanatory variables regarding average travel distance of flyover users.

Explanatory variables	Average travel distance of flyover users (kilometres)
Decreased travel time	11.18
Trip purpose (education)	10.64
Trip purpose (recreation)	8.91
Car ownership	13.09

3.4 Average trip frequency between flyover and non-flyover users

Flyover users generated more trips than non-flyover users. It was estimated that flyover users generated an average of 8.38 trips per week; on the other hand, non-flyover users generated an average of 8.05 trips per week.

3.4.1 Factors affecting trip frequency between flyover and non-flyover users

3.4.1.1 Age

The highest average trips per week (8.58) were made by flyover users with an age range of 30-44 years. The second highest amount of average trips per week, (8.53) was made by flyover users with an age range of 15-29 years. The lowest average trips made per week by those with an age range of 60 years or above, was 6.32. The highest average trips per week (8.81) were made by non-flyover users with an age range of 30-44 years and 45-59 years. The lowest number of average trips per week made by non-flyover users with an age range of 60 years or above was 6.20 (Fig. 6).

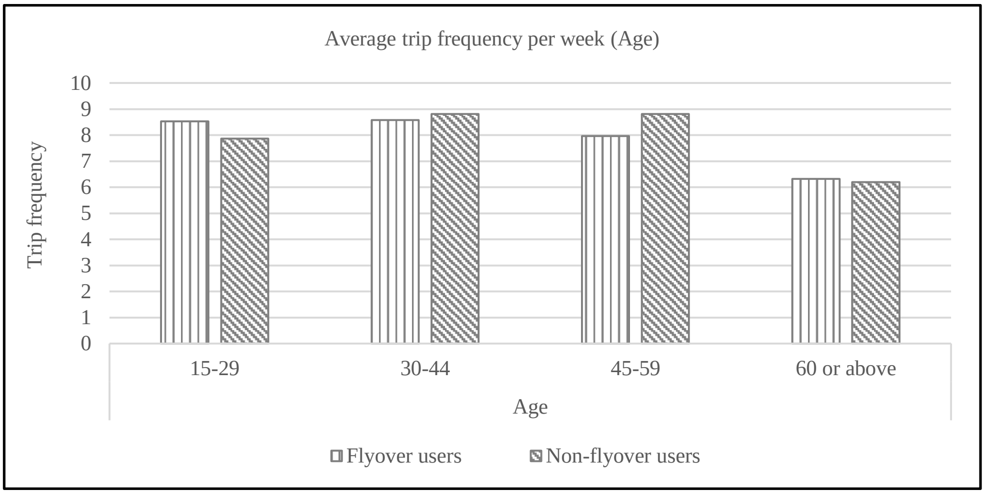

Fig. 6. Average trip frequency of flyover and non-flyover users based on age.

Most flyover users (11.67%) within an age range of 15-29 generated two induced trips per week. The induced trips made by flyover users (17.05%) within an age range of 30-44 years were two per week. Around 23% of flyover users within an age range of 45-59 years and 24.24% of flyover users within an age range of 60 years or above generated two induced trips per week. Non-flyover users (25.80%) within an age range of 15-29 years generated two induced trips per week. Only 6.02% of non-flyover users within all age categories generated four induced trips per week.

3.4.1.2 Gender and occupation

The average trip per week of females (8.82) was higher than males (7.98). Working flyover users made an average of 8.52 trips per week, whereas students made an average of 8.00 trips per week. Female non-flyover users (8.35) made more trips per week than males (7.75). A similar result was found in relation to the occupation of non-flyover users. The number of average trips per week made by working non-flyover users was 8.28, whereas the number of average trips made by students was 7.60 (Fig. 7).

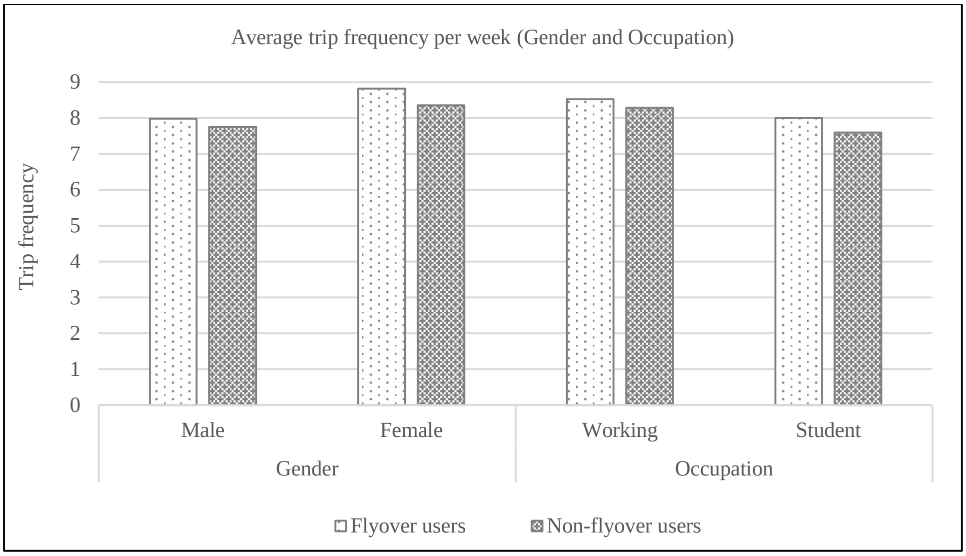

Fig. 7. Average trip frequency of flyover and non-flyover users based on gender and occupation.

Around 18% male and 14% female flyover users generated two induced trips per week. More working flyover users (16.85%) and students (13.39%) also generated two induced trips per week. Male and female non-flyover users (16.47%) generated two induced trips per week. Only 1.17% of male non-flyover users generated six induced trips per week. Working non-flyover (13.79%) and students (23.07%) generated two induced trips per week.

3.4.1.3 Income and education

Differences across the income scale were also of interest. Lower middle income flyover users generated more trips per week (9.70) compared to other income groups. The second highest number of average trips per week was generated by middle income flyover users (8.75). The lowest number of average trips per week was generated by higher income flyover users (7.26). Flyover users, who had a primary school education generated more trips per week (9.45) compared to other groups. The lowest number of average trips per week (7.87) was generated by the flyover users, who had a diploma or certificate course education (Fig. 8).

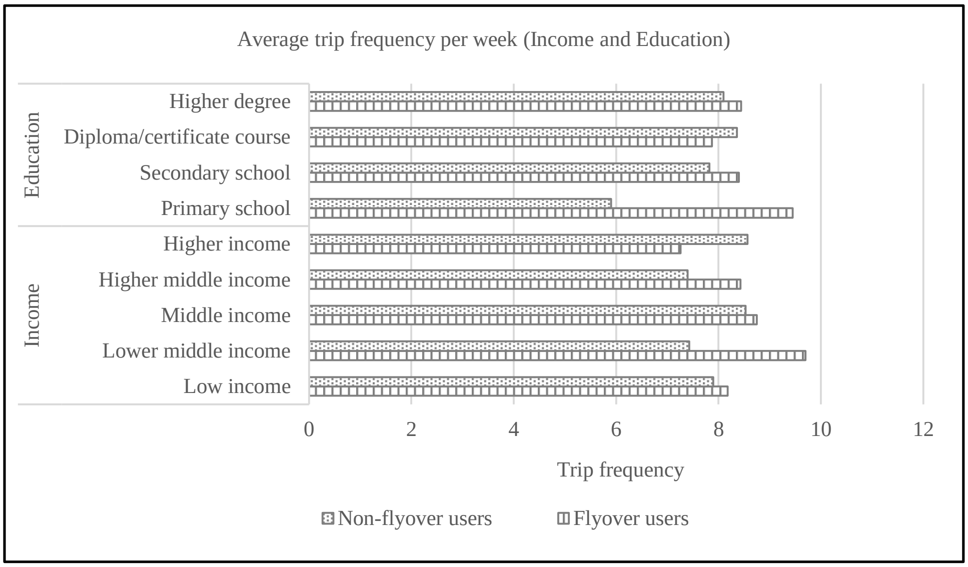

Fig. 8. Average trip frequency of flyover and non-flyover users based on income and education.

Higher income non-flyover users generated more trips per week (8.57) than others. Middle income non-flyover users generated 8.53 trips per week. The lowest number of average trips per week was generated by higher middle income non-flyover users (7.40). Non-flyover users with a diploma or certificate course education generated more trips per week (8.36) compared to other groups. The lowest numbers of average trips per week (5.90) was generated by non-flyover users with a primary school education.

Most flyover users from low income to higher income generated two induced trips per week, whereas higher income flyover users (33.71%) made two to six induced trips per week for regular trip purposes. The rate of induced trips also varies with the education level of flyover users. Most flyover users (15.52%) with a higher university degree generated two induced trips per week. The highest induced trips that were generated by middle income non-flyover users, (36.84%) were two per week. No higher income non-flyover users generate induced trips. Non-flyover users with a higher university degree (20.31%) generated two induced trips per week. Most non-flyover users with a primary and secondary school education did not generate induced trips.

3.4.1.4 Home ownership, household size and car ownership

Flyover users who did not own a house generated more average trips per week (8.79) compared to the flyover users who owned a house (7.58). Flyover users with three family members generated more average trips per week (9.23) compared to flyover users with other household sizes. The average trips per week were higher among flyover users who did not own a car (8.45) compared to the flyover users who owned a car (8.17) (Fig. 9).

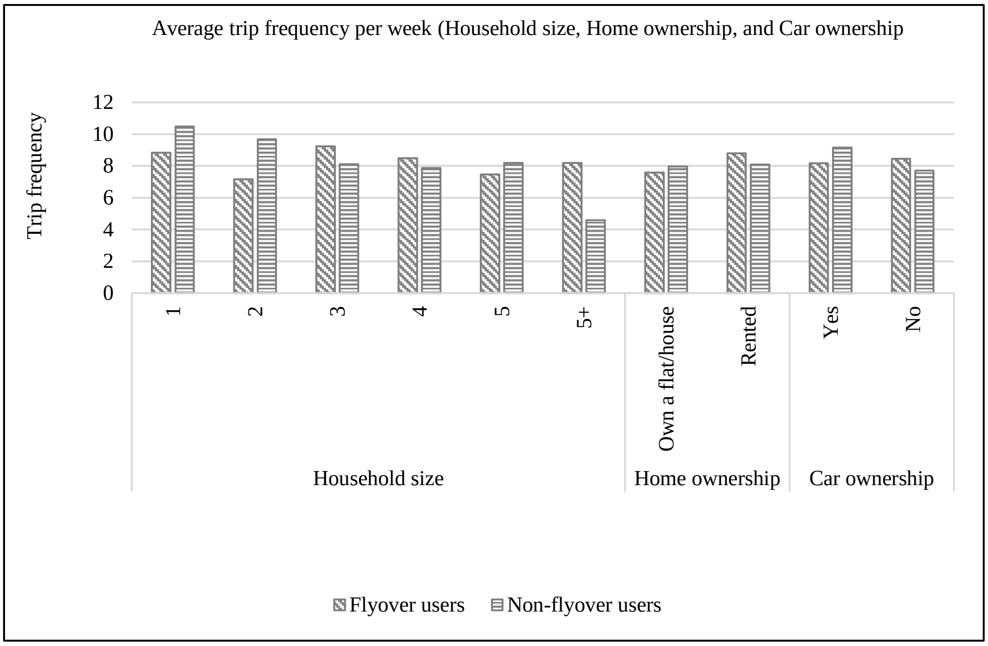

Fig. 9. Average trip frequency per week of flyover and non-flyover users based on household size, home ownership and car ownership.

Non-flyover users who lived in a rented house generated more average trips per week (8.09) than others. Non-flyover users who lived alone generated an average of 10.48 trips per week. The highest number of trips per week generated by non-flyover users with two family members was 9.68, whereas non-flyover users with more than five family members generated the lowest number of trips (4.60) per week. The highest average trips per week were generated by non-flyover users who owned a car (9.15) compared to those who did not own a car (7.71).

The number of induced trips generated by flyover users varies from two to twelve trips with those who own a home, household size, and car ownership. More flyover users (13%) who lived in rented accommodation generated two induced trips per week. Flyover users (15.79%) with a household size of four made more induced trips (two trips per week) compared to other household sizes. The rate of induced trips differs with car ownership of flyover users. Most flyover users (20.45%) who did not own a car made two to four induced trips per week for regular travel purposes.

Non-flyover users who lived in their own house did not generate more than four induced trips per week. More non-flyover users who lived in a rented house generated two induced trips (18.51%). Only 1.85% non-flyover users who lived in a rented house generated six induced trips per week. Non-flyover users including all household sizes (16.66%) generated two induced trips per week. More non-flyover users who did not own a car generated two induced trips (25%), followed by four induced trips (8.92%) per week.

3.4.1.5 Trip purposes

Flyover users who travelled for education purposes generated more average trips per week (9.55) (Fig. 10). The lowest number of average trips per week was generated by flyover users who travelled for shopping purposes (2.68). Non-flyover users travelling for work purposes generated more average trips per week (9.08). The lowest number of average trips per week was generated by non-flyover users who travelled to visit family with an average of two trips per week.

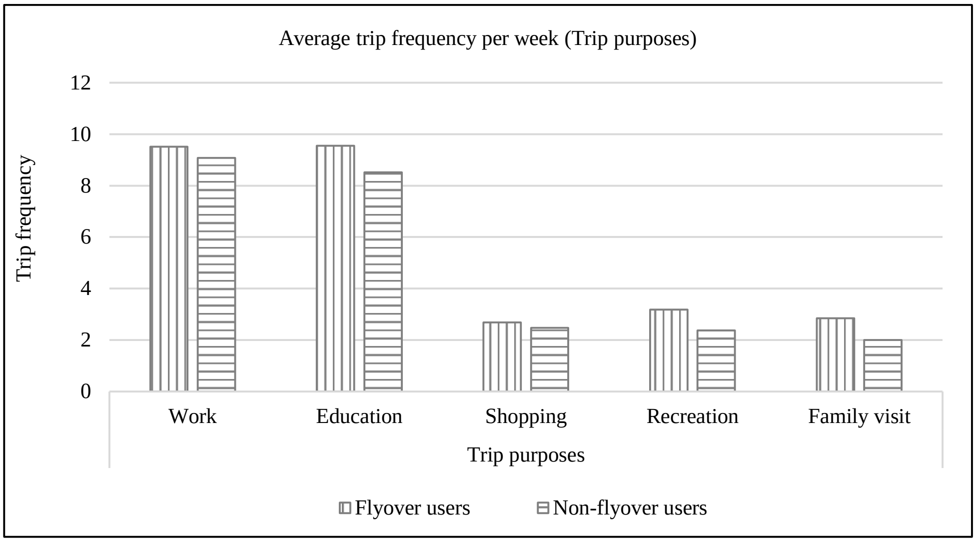

Fig. 10. Average trip frequency of flyover and non-flyover users according to trip purposes.

Most flyover users (23.86%) made from two to four induced trips per week travelling for work purposes. Flyover users travelling for shopping and recreational purposes did not make more than two induced trips per week. Flyover users travelling for educational reasons generated two induced trips per week. Non-flyover users who travelled for shopping and recreational purposes did not generate more than two induced trips per week. There were no induced trips generated by non-flyover users travelling for family visits. Most non-flyover users generated two induced trips per week (20.75%), travelling to and from work.

3.4.1.6 Changes in travel distance and time

The highest number of average trips per week (8.73) was generated by flyover users, whose travel distance increased. Flyover users who did not change their travel distance generated an average of 8.51 trips per week. The lowest number of average trips was generated by flyover users, whose travel distance decreased (6.73).

Flyover users who decreased their travel time or travel time savings generated more average trips per week (8.24). However, the lowest number of average trips per week (7.45) was generated by the flyover users, whose travel times increased following the construction of flyovers. Non-flyover users whose travel time was constant generated more average trips per week (8.62) compared to others. There were no trips made by non-flyover users for travel time savings (Fig. 11).

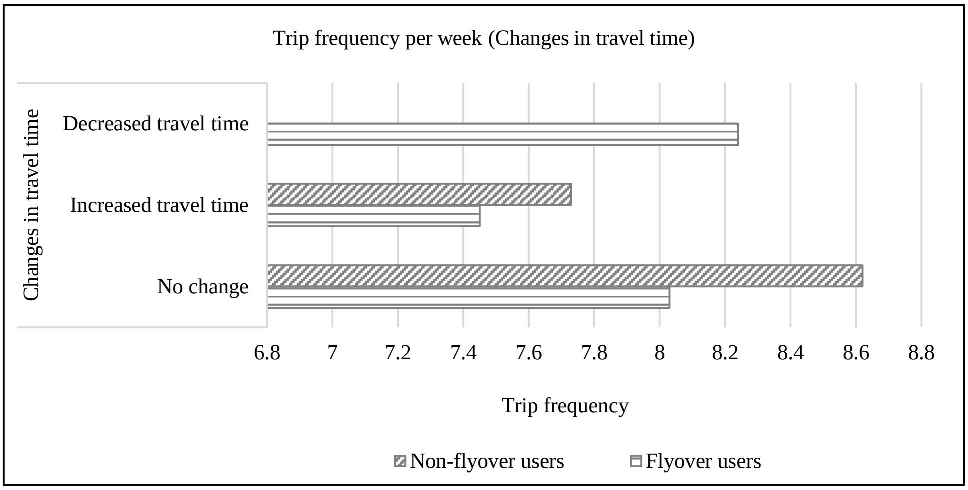

Fig. 11. Average trip frequency of flyover and non-flyover users based on changes in travel time and distance.

More flyover users (15.63%) generated two induced trips per week, whereas 7.03% of flyover users generated four induced trips per week for travel time savings. There were no changes in travel distance and no induced trips generated by non-flyover users for travel time savings.

There were no non-flyover users who indicated that their travel time decreased for regular trip purposes. All of the socio-economic and travel related variables were tested in the model separately to identify the significant variables that influence induced trips of flyover and non-flyover users. Only the significant variables such as gender (male), low income, lower middle income and household size (04) were used to determine induced trips of flyover users. These variables were also tested for non-flyover users. However, no variables were statistically significant. Therefore, modelling induced trips of non-flyover users were excluded from the analysis.

3.4.2 Modelling induced trips of flyover users

An independent samples t-test was conducted to compare the changes in trip frequency made by flyover and non-flyover users. There was a significant difference in trip frequency between the two groups, t (560) = 2.77, p <0.00, two-tailed with flyover users (M = 1.12, SD = 2.65) travel more than non-flyover users (M = 0.28, SD = 1.95). The magnitude of the differences in the means (mean differences = 0.83, 95% CI: 0.24 to 1.43). The flyover has small effect (Cohen’s d = 0.23, eta squared = 0.01).

The Pearson correlation analysis and VIF were measured to identify the strength of the association and multicollinearity amongst the explanatory variables. The results of this analysis show that there was a weak association amongst the explanatory variables and none of the explanatory variables had a VIF greater than 2 (Table 5 and 6).

Table 5. Correlation co-efficients among explanatory variables.

Variables	Decreased Travel time	Gender Male	Low income	Lower middle income	Household size (04)
Decreased travel time	-	-.010	.085	-.004	.108[a]
Gender (Male)		-	-.217[b]	-.061	-1.055E-1[a]
Low income			-	-.150[b]	.207[b]
Lower middle income				-	-8.975E-2[a]
Household size (04)					-

Note: ‘a’ and ‘b’ indicates Pearson correlation is significant at the 0.01 and 0.05 level (2-tailed) respectively.

Table 6. Multicollinearity statistics of explanatory variables.

Explanatory variables	VIF
Decreased travel time	1.016
Gender (male)	1.074
Low income	1.118
Lower middle income	1.046
Household size (04)	1.111

The model predicted that if travel time savings were increased by one unit (corresponding to a minute), the change in trip frequency also increased by 0.350 unit in terms of numbers, holding all other explanatory variables constant (Table 7). The model also predicted that if a household size of four people was increased by one unit, the change in trip frequency also increased by 0.313 units. However, the model predicted that if the number of low income people was increased by one unit, the change in trip frequency decreased by 0.499, units holding all other explanatory variables constant. In addition, the model predicted that if the number of males was increased by one unit, the change in trip frequency decreased by 0.305 units. The model also predicted that if the number of lower middle income people was increased by one unit, the change in trip frequency also decreased by 0.575 units, holding all other explanatory variables constant. The R Square shows that the model related to the change in trip frequency of individuals explained 4% of the variance in the data. The model was also statistically significant ($P<0.05$) and the data was suitably fit to model.

Table 7.Multiple linear regression model parameter estimates for flyover users.

Explanatory variables	B	Std. Error	t	Significance
Decreased Travel time (minutes)	.350	.198	1.767	.078[c]
Gender (Male)	-.305	.142	-2.149	.032[b]
Low income	-.499	.186	-2.675	.008[a]
Lower middle income	-.575	.317	-1.815	.070[c]
Household size (04)	.313	.143	2.184	.029[b]

Note: a, b and c indicates the regression co-efficient is significant at the 0.01, 0.05 and 0.10 level

Table 8. Descriptive statistics of the significant explanatory variables regarding average trip frequencies of flyover users.

Explanatory variables	Average trip frequency (per week)
Decreased travel time (minutes)	8.24
Gender (male)	7.98
Low income	8.18
Lower middle income	9.70
Household size (04)	8.50

4. Discussion

The research findings show that flyovers generate induced travel, and non-flyover roads did not generate induced travel for regular trip purposes. Our study also reveals that there is no impact on induced travel kilometres generated by transport infrastructure (flyovers) and non-flyover roads. The distance travelled by non-flyover users is fixed because they did not change their trip origin and destination following the construction of flyovers. Flyover users travel less kilometres due to savings within their travel times, however, they also travel a greater distance than non-flyover users. Flyover users generate more trips for regular travel purposes than non-flyover users. The research finds that if travel time saving increases with the construction of transport infrastructure such as flyovers, the number of average trip frequencies per week also increase. However, policy makers do not consider induced trips when making plans for the construction of transport infrastructure. In addition, estimates of proposed transport infrastructure are based on the present operation of traffic, and due to the omission of induced trips, the benefits of travel time savings are overestimated. Compounding this, there may be spill-over effects (traffic coming from other routes), which can lead to more traffic congestion.

The research findings obtained from the linear multiple regression analysis confirm existing research: the construction of new or improved roads, motorway, and highways generates induced travel (Özuysal and Tanyel, 2008; Rohr et al., 2012; Shengchuan et al., 2012; Zeibots, 2003). All results support that the construction of transport infrastructure, such as flyovers, generate induced travel. The study demonstrates that individuals did not travel more kilometres due to the construction of transport infrastructure. The results also comply with the findings of existing research. Prakash et al. (2001) identified that people did not travel more kilometres due to expenditure on road improvements or new road construction. This research reveals that individuals did not travel more kilometers due to the construction of flyover infrastructure, as most flyovers were constructed on the same roadway intersections in order to reduce traffic congestion. In addition, most flyover users did not change their trip origin and destination after the construction of the flyover.

Induced travel kilometres and induced trips of flyover and non-flyover users varies with their socio-economic and travel related characteristics. However, the most significant factors that impact on induced travel kilometres of flyover users are a) travel time savings, b) trip purpose (education), c) trip purpose (recreation), and d) car ownership. Flyover users with no change in their commute time travelled a greater distance, whereas non-flyover users whose commute time increased travelled further. The study also identified that flyover users travelling for educational purposes generate more induced travel kilometres (one to nine kilometres) than others. Flyover users who did not own a car generated one to nine kilometres of induced travel than flyover users who had a car (one to four kilometres).

Induced trips of flyover users are also influenced by significant socio-economic factors such as travel time savings, gender (male), low income, lower middle income, and flyover users who lived in a household of four. Flyover users also generate more induced trips (two to four) per week due to a decrease in their travel time. No induced trips are generated by non-flyover users for travel time savings. The research revealed that male and female flyover and non-flyover users within all age categories generate two induced trips per week. Flyover users in all income groups generate two to twelve induced trips per week, whereas higher income flyover users generate two to six induced trips per week. No induced trips are generated by higher income non-flyover users. More flyover users with a household size of four generate two induced trips per week compared to other house sizes, whereas non-flyover users within all household sizes generate two induced trips per week.

There were no statistically significant factors that influenced induced travel kilometres and induced trips of non-flyover users. Researchers have also identified that individuals' living style, residential location and job location can also influence travel distance and trip frequency (Ellder et al., 2014). These additional variables can be collected and added to the model to identify the impact of these variables on induced travel kilometres and induced trips of flyover and non-flyover road users. Adding these variables to the model can contribute to extended knowledge in measuring induced travel kilometres and induced trips of flyover and non-flyover road users. The knowledge regarding the socio-economic and travel characteristics that influence induced travel kilometres and induced trips is needs to be considered before construction of any transport infrastructure such as flyovers. The existing transport policies such as the urban transport policy should include all socio-economic and travel related aspects in feasibility studies when providing a new transport infrastructure. Otherwise, there may be little benefit of travel time savings due to the ignored induced travel demand effects of transport infrastructure.

5. Conclusion

Flyover users generate more induced trips in an effort to save travel time for their regular trip purposes. There are no evidences to generate induced travel kilometers for flyovers users. The results also true for non-flyover users. Average travel time, distance and trip frequency also varies not only for construction of flyovers, but also with respondent's socio-economic and travel characteristics, such as age, gender, income, occupation, education, household size, home ownership, car ownership, trip purposes, and changes in travel distance and time. The research suggests that transport infrastructure development such as flyovers generates 0.350 induced trips due to a one minute savings in travel time. These trips should be considered in the transport policies to estimate traffic growth when providing new transport infrastructure in the context of developing countries, particularly in Dhaka, Bangladesh.

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