ARE MOTORCYCLE COMMUTERS DIFFERENT TO THOSE WHO USE CAR OR PUBLIC TRANSPORT?

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ABSTRACT

Motorcycles, or powered two wheelers (PTW), have received less attention as a commuting mode than others such as car, public transport and bicycle. More common in warmer countries such as in southern European countries and in densely populated countries, their narrow size and flexibility offer advantages to users in congested urban settings and in other environments too. With recent evidence of increasing demand for more flexible modes e.g. shared bike schemes in Europe, the research presented here looks at use of the motorcycle for work trips in a northern European country - Ireland. One of the questions explored was to see if the profiles of motorcycle work trip users were closer to that of other modes such as bicycle users or drive alone car users - or if motorcycle users had a different profile entirely - as a means of better understanding the potential of the motorcycle mode in satisfying particular user needs. The place of work census data for 2011 was used to examine differences across a number of variables: gender, age, household composition, industrial group, urban vs rural, number of students in households and work trip travel time. The research also examines which of a number of variables are most relevant in determining work trip mode choice with particular emphasis on distinguishing the characteristics of motorcycle work trip users using a multinomial logistic regression. The research finds that the motorcycle work trip user profile most closely resembles drive alone car user profiles across a number of variables.

Keywords: *motorcycle, flexible mode, work trips*

INTRODUCTION

Urban traffic congestion continues to pose difficulties for transport users and for local authorities. The marked recent growth in more flexible modes such as the bike-sharing phenomenon demonstrate the latent demand for modes that are convenient, not only in space but also in time. Modes that offer insulation against congestion continue to gain traction as congestion continues to be an intractable aspect of most urban settings. Motorcycles or powered two wheelers (PTW) are more flexible than the car mode particularly in countries where lane splitting is allowed. In the case of Ireland, the Road Safety Authority *(1)* advises against lane splitting citing significant dangers but strictly speaking it is not illegal and is commonly practiced by motorcycle users. Motorcyclists are also allowed to use some bus lanes but according to their local association many do not distinguish between those they are allowed to use and those they are not and many tend to use all bus lanes *(2)*.

Much of earlier research on motorcycles focused on their impact on air pollution but more recent research looks at the impacts on congestion e.g. the work of the Department for London in the UK which examined the journey time and emissions of PTWs in bus lanes *(3)*. As part of the work, police assigned riders to survey the routes with one PTW travelling in bus lanes where available and a PTW and a car travelling in general traffic lanes. They found that PTW using bus lanes, where available, took an average of 2 mins 29 secs per km compared with 2 mins 46 sec per km in general lanes – cars took on average 3 mins 55 sec per km on the same route. In parallel, they found that PTW use of bus lanes cuts CO_2 emissions by an average of 0.4% and 9% and NOx by an average of between 0.4% and 10.1%. *(3)*. Other work in Belgium examined the impact of modal shift on traffic flow and traffic congestion in a case study in which the traffic on the Leuven-Brussels motorway journey was simulated and substitution of 10% of cars by motorcycles. They found that there were 1,925 reduced vehicle hours in the modelled scenario as a result. They also noted a 6% lower emission cost, 1% of which could be attributed to the replacement of cars by motorcycles and 5% to the smoother traffic flow *(4)*.

In 2002, Wigan *(5)* put forward the case for the use of motorcycles as an effective means of transport with many valuable characteristics but a high level of vulnerability. At that stage, he noted that the mode had yet to be taken seriously on an adequate scale, and the necessary understanding of travel and choice characteristics was still wanting. In 2006, Bruge et al *(6)* developed a motorcycle ownership model for the UK using data from the UK National Travel Survey, the Family Expenditure Survey and a survey of motorcycle users. More recently again, Rose et al *(7)* aimed to enhance understanding of the role of PTWs for commuting in the context of large Australian cities using census data and a travel survey of motorcyclists. Despite issues related to the difficulty in surveying motorcycle users, they found that survey respondents highly valued the utilitarian benefits of PTW commuting such as free parking, travel time savings and parking near their destination. They also found that that PTW users were predominantly male and tended to be highly educated with high incomes.

Cirilli et al *(8)* examined spatial structure and CO_2 emissions due to commuting in analysis on Italian urban areas and noted a 6.96% of commuters using motorcycles there for commuting; relatively high compared with other countries. Research in another southern European country *(9)* in 2007, noted increased PTW ownership and related traffic. They noted that there was a clear difference between vehicle ownership rates and vehicle usage rates per vehicle type and found that mopeds and motorcycles are preferred for particular types of trips e.g. travelling in residential areas and weekdays during daytime. PTW users avoided travelling on motorways and at nighttime due to the perceived higher safety risks.

Ireland is an island on the west of Europe, with a population of 4.7 million. In 2011, 2.7 million people commuted to work, school and college with 66% of workers driving to work and of those driving to work females exceeded males *(10)*. Ireland is predominantly rural, geographically speaking, but there are significant population centers in 5 cities. The Greater Dublin area (a term used to describe the commuter belt around Dublin including neighboring counties) currently has a population of 1.9 million and is described in European terms as a medium-sized city.

When comparing the urban based travel characteristics with rural areas in Ireland, the cities dominate in terms of public transport use with 21% of commuters in Dublin using it and less than 6% in the other cities. Cycling to work was most popular in Dublin at 6% followed by Galway at 5%. The commuter belt around Dublin is substantial and more than 1 in 7 within that area had travel times of an hour or longer to their work place. At the other end of the spectrum, in many rural based towns, between 40% and 50% of work trips were less than 15 mins *(10).*

The research presented here aims to supplement the work of previous researchers in helping to better understand the profile of PTW users, in different locations and conditions. The work uses data from the 2011 Irish census. The next section describes the methods used followed by a presentation of the results. The paper ends with a summary of conclusions.

METHODS

Data

The data used in this study was taken from the 2011 census of the Irish population. The census is conducted every five years by the Central Statistics Office (CSO) and includes all individuals present in the country on that particular date. From the census data an anonymised set of records called the Place of Work Census of Anonymised Records (POWCAR) database focuses on transport related aspects of the country's population *(11)*. Personal, household and travel characteristic variables are defined for each entry. These include age, gender, highest level of education completed to date, socio-economic group, household composition, year household was built, residential area type, mode of travel to work, school or college, time of departure to work, school or college, journey time to work, school or college, number of cars or vans available for use in the household, location of usual residence and location of place of work, school or college. Respondents are responsible for reporting on the variables in the census. Unfortunately data on income is not available.

Of the total 1,467,006 individuals making the work trip and included in the analyses, 7,619 individuals travel to work by motorcycle which is less than 1%. The frequency distributions that follow below are presented in percentages rather than in absolute terms so that observation of the overall profile per mode can be more easily interpreted and compared across modes.

Statistical Analysis

Logistic regression can be used to predict a categorical dependent variable on the basis of continuous and/or categorical independents, to determine the effect size of the independent variables on the dependent and to rank the relative importance of the independent variables. It applies maximum likelihood estimation after transforming the dependent into a logit variable. The logit is a natural log of the odds of the dependent variable equalling the highest value and in this way logistic regression estimates the odds of a certain event occurring. The predictive success of the logistic regression can be assessed by looking at the classification table, showing correct and incorrect classifications of the dependent variable. Goodness of fit tests used are the likelihood ratio test and the Nagelkerke statistic *(12)*. The logistic regression equation is:

$$z = b_0 + b_1 X_1 + b_2 X_2 + \cdots + b_k X_k \quad (1)$$

where z = log odds of the dependent variable = ln(odds(event)) or the logit
b_0 = constant
b_1, b_2, etc = logistic regression coefficients
X_1, X_2, etc = dependent variables.

Exp(b) is the odds ratio for an independent variable i.e. the natural log base e raised to the power of b. The odds ratio is the factor by which the independent variable increases or (if negative) decreases the log odds of the dependent variables. Exp(z) is the odds ratio of the dependent variable, being the odds that the dependent variable equals the level of interest rather than the reference level.

The likelihood is a probability that the observed values of the dependent may be predicted from the observed values of the independents. The log likelihood (LL) is its log and varies from 0 to minus infinity. LL is calculated in the modelling by iteration using maximum likelihood estimation. Because -2LL has approximately a chi-square distribution, -2LL can be used for assessing the significance of logistic regression. In general, as the model becomes better, the -2LL will decrease in magnitude.

RESULTS AND DISCUSSION

Frequency Distribution Profiles

The frequency distribution profiles of user and household characteristics were first compared across different modes to observe if motorcyclist work trip users and their households were markedly different to those of other modes. The following variables were considered: number of household residents, number of workers in households, number of students in households, household composition, gender of work trip maker, highest education level, age, work trip journey time and work trip departure time.

The frequency distribution of numbers in households against work trip mode is shown in Figure 1 and they use the primary axis in the figure. The mean and confidence intervals (CI) for analysis of variance (ANOVA) tests between the numbers of people in households for the different work trip transport modes are also plotted on the figure using the secondary axis ($F= 24613$, $P < 0.001$). The frequency distribution profile is very similar for the motorcycle and drive alone (single occupancy car use) groups and ANOVA post hoc tests confirm this with the CIs overlapping as shown in the figure. The mean of the number of persons in households for the car passenger group is much higher than for the other groups and that there are similarities between the cycle and work from home groups with similar percentages of one person, two person etc households in both.

The second variable to be examined was the number of employed persons per household. The frequency distribution and comparison of means by work trip transport mode is presented in Figure 2. Some groups show more similarity with each other such as the rail and motorcycle groups and separately the drive alone, van and other incl truck groups, as can be seen in the overlap of CIs in Figure. ($F = 15338$, $P < 0.001$).

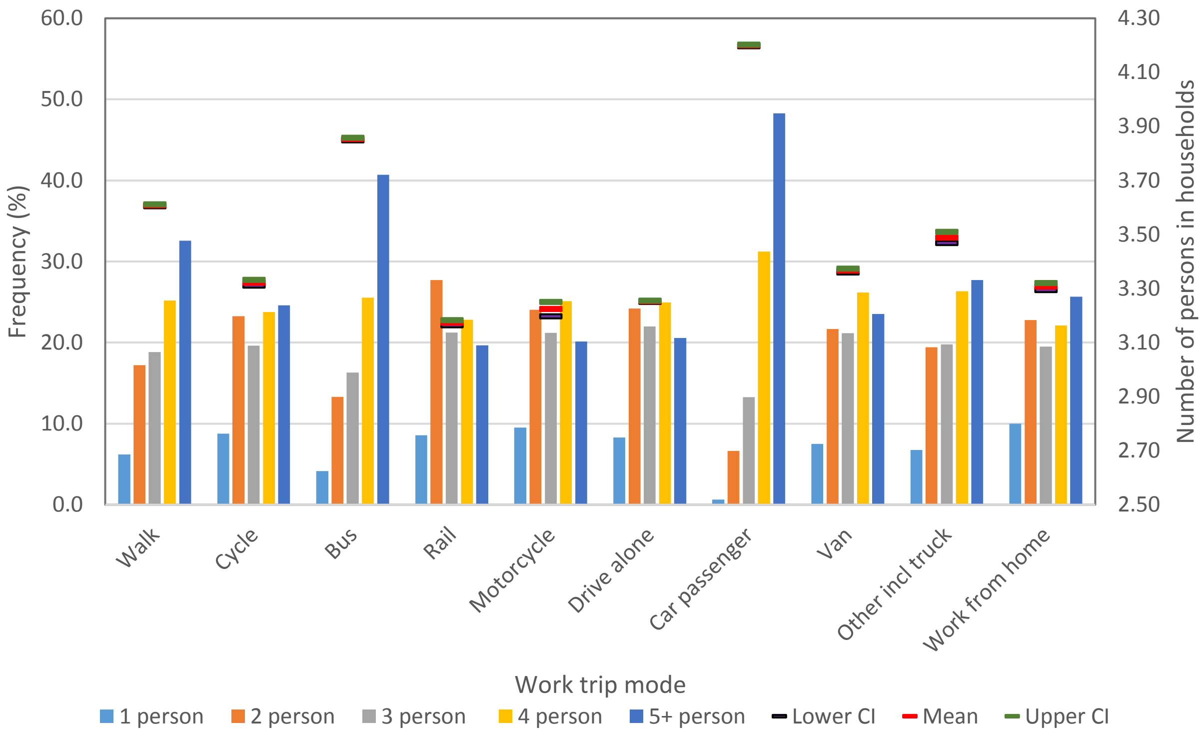

FIGURE 1 Frequency distribution and comparison of the means of number of persons in households by work trip mode

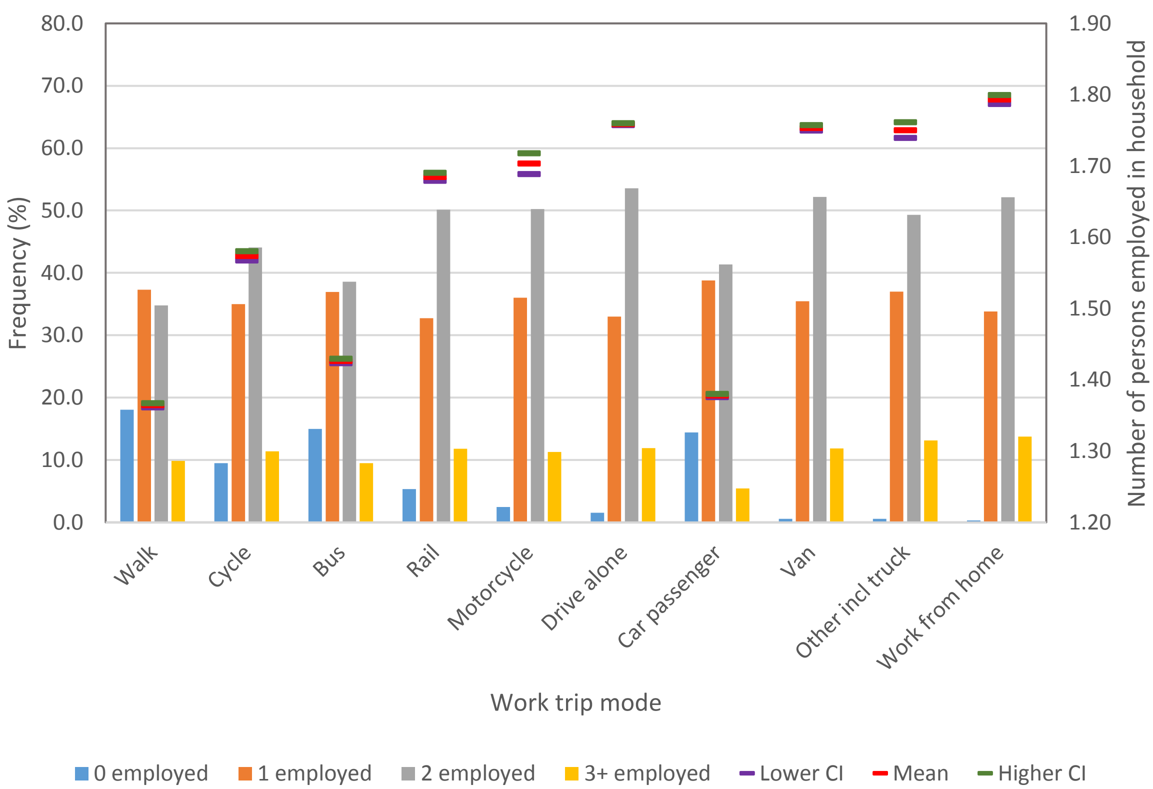

FIGURE 2 Frequency distribution and comparison of mean numbers of persons employed in households by work trip mode

The next variable under consideration was the number of students per household. The frequency distribution is shown in Figure 3 and the CIs from the comparison of means analysis indicate that the mean for the motorcycle group is statistically significantly similar to the drive alone, van and work from home groups. (F = 51987, P < 0.001). The means of the number of students in households in other groups such as the walk, cycle, bus and car passenger groups are found to be higher and statistically significantly different to the motorcycle group.

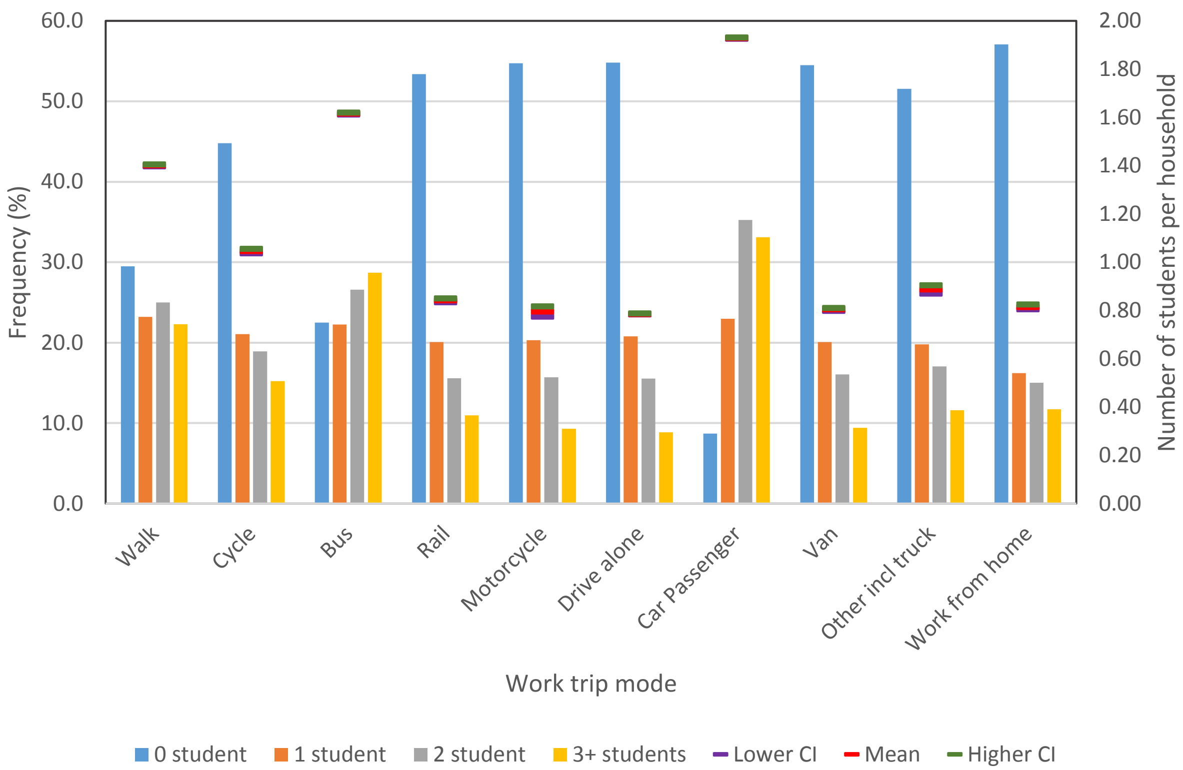

FIGURE 3 Frequency distribution and comparison of mean numbers of students in households by work trip mode

Household composition was investigated next with the frequency distributions shown in Figure 4. Statistical comparison of means could not be conducted in this case due to the nature of the categorisation. The drive alone, van, rail and motorcycle distributions are remarkably similar.

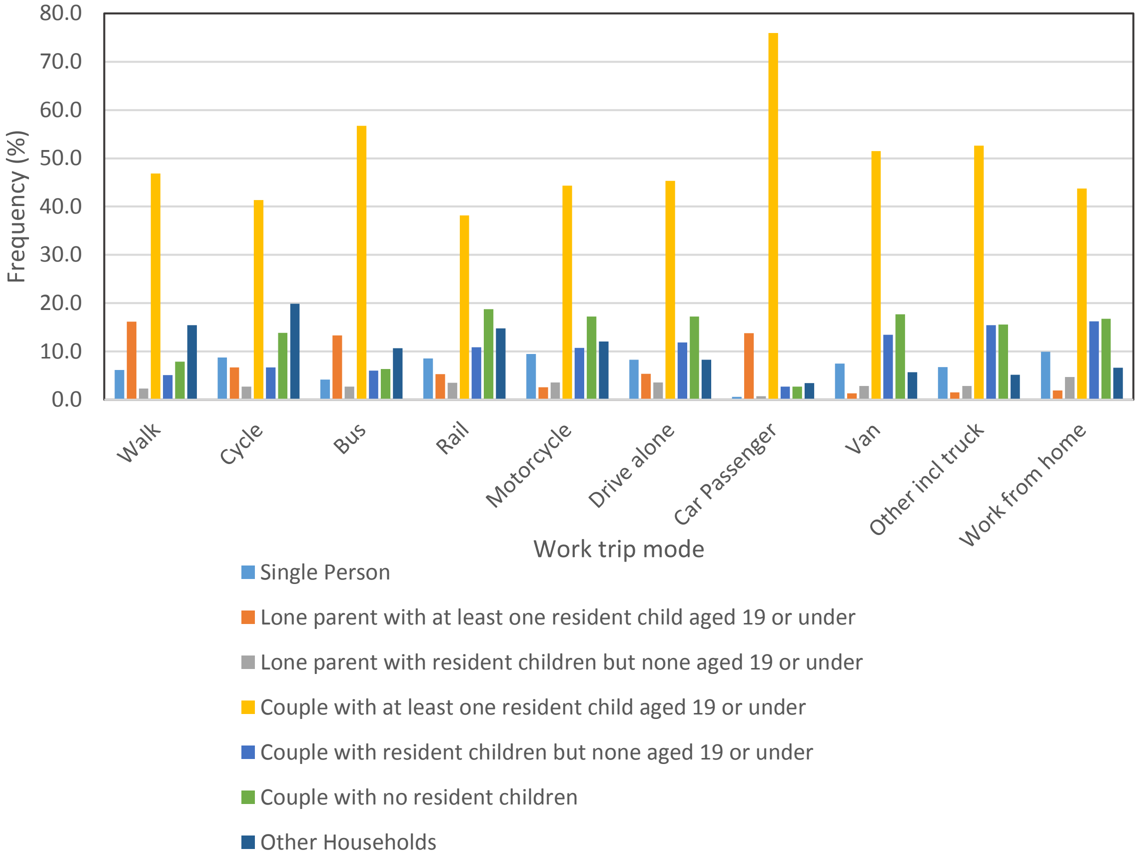

FIGURE 4 Frequency distribution of household composition by work trip mode

Six times the number of males compared with females use motorcycles to get to work, as can be seen in Figure 5. Only the van and other incl truck groups show higher ratios of men to women. A three-fold difference between males and females exists for the cycle and work from home groups with a much more equal distribution between males and females evident for the walk, bus, rail, drive alone and car passenger groups.

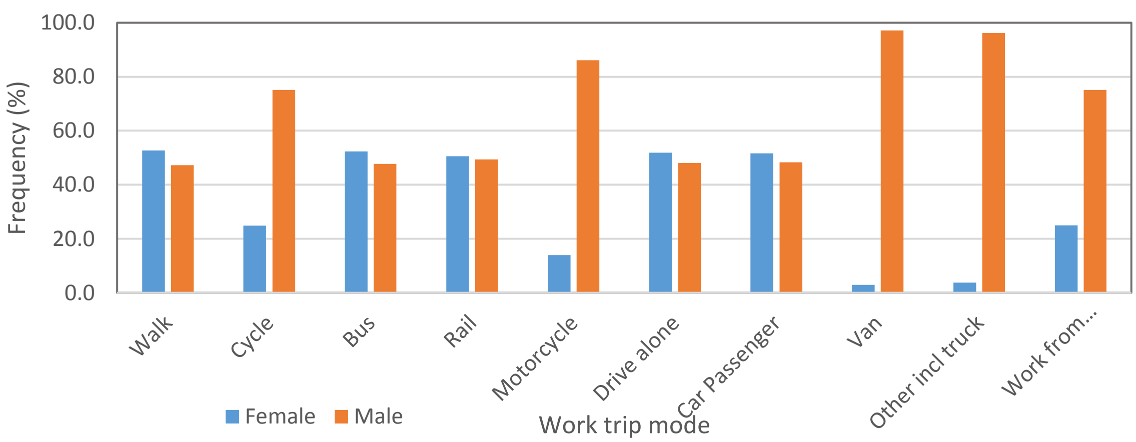

FIGURE 5 Frequency distribution of gender by work trip mode

In Figure 6, the age frequency profiles for the motorcycle and drive along groups are similar and the CIs of the means for the two groups overlap indicating a high degree of similarity. (F = 6064, P < 0.000). Higher proportions of walk, cycle, bus and rail groups are in the 20-35 age groups with walk and cycle having somewhat higher age groups means than the bus and rail groups. The working from home group has the highest mean age of 49 years.

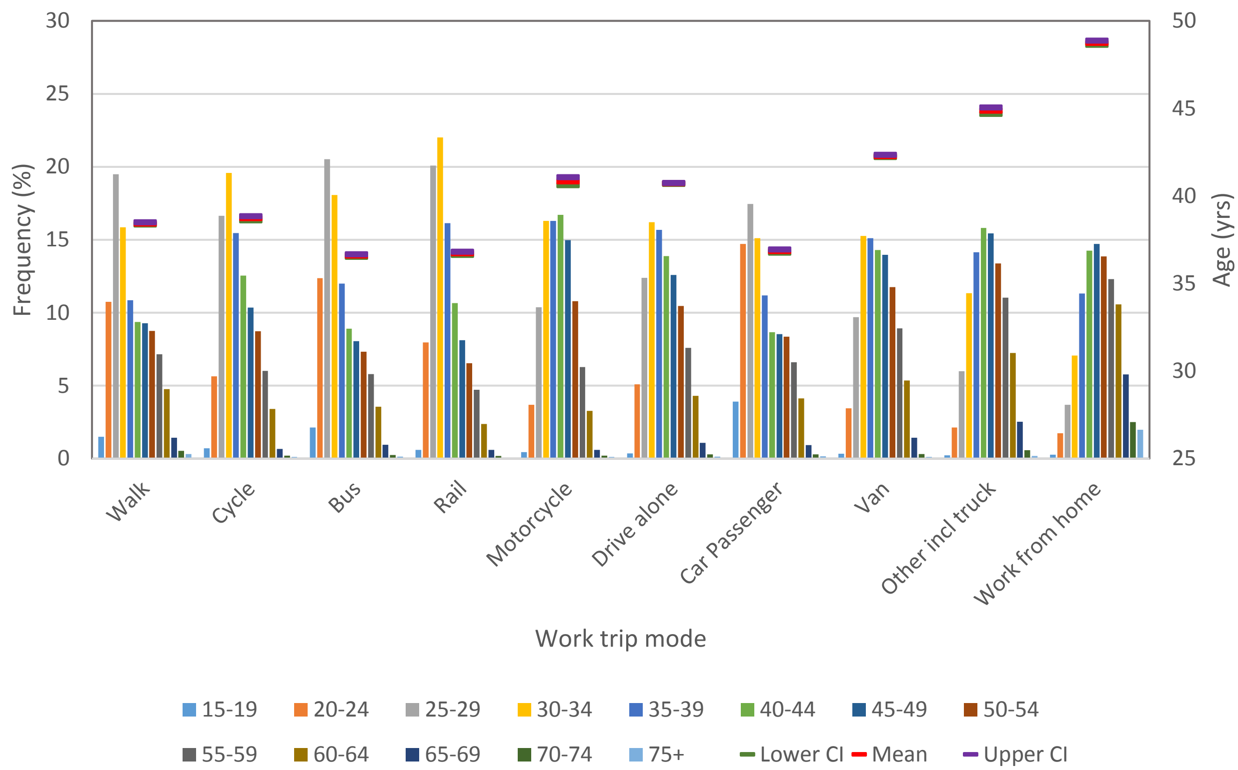

FIGURE 6 Frequency distribution and comparison of means for age by work trip mode

The frequency distributions for socio-economic group (SEG) by work trip mode are presented in Figure 7. The distributions for the motorcycle, drive alone and car passenger groups have some similarities but those for the other groups are more distinctive with less similarity appearing between groups e.g. a relatively high proportion of higher professionals travel by rail with much lower semi-skilled workers travelling by that mode.

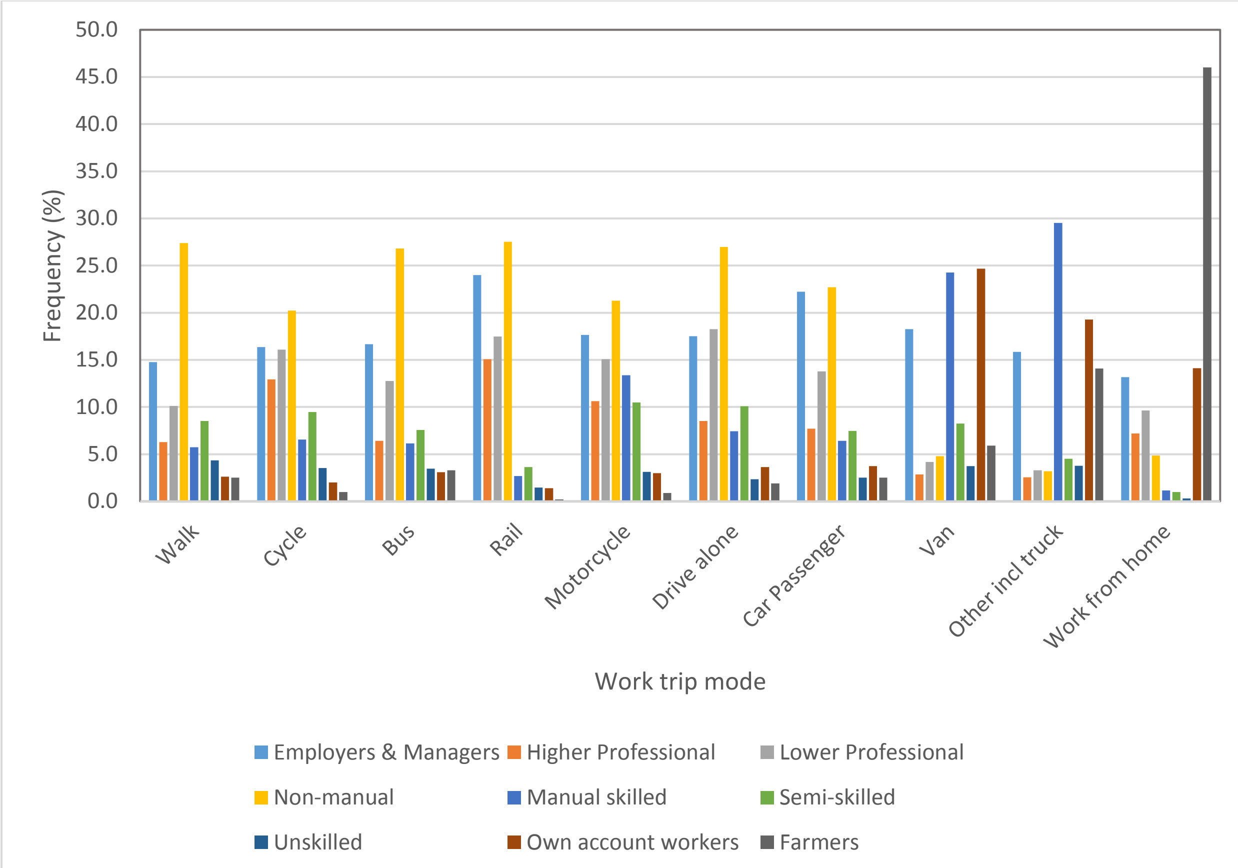

FIGURE 7 Frequency distribution of socioeconomic groups (SEG) by work trip mode

Frequency distributions for work trip travel time are presented in Figure 8 along with the mean and associated CIs for each mode. (F = 64320, P <0.000). Similar distribution shapes are evident for the motorcycle, drive alone, van and other incl truck groups but markedly different profiles exist for the walk, cycle and car passenger groups; all having very high proportions of trips below 15 minutes. The rail group stands out with having the largest proportions of longer trips, as might be expected. The difference in the means of work trip travel time between rural and urban areas is shown in Figure 9. In most cases the urban trip is shorter than the rural trips. The motorcycle and drive alone distances in both cases are closest when making a comparison across the modes.

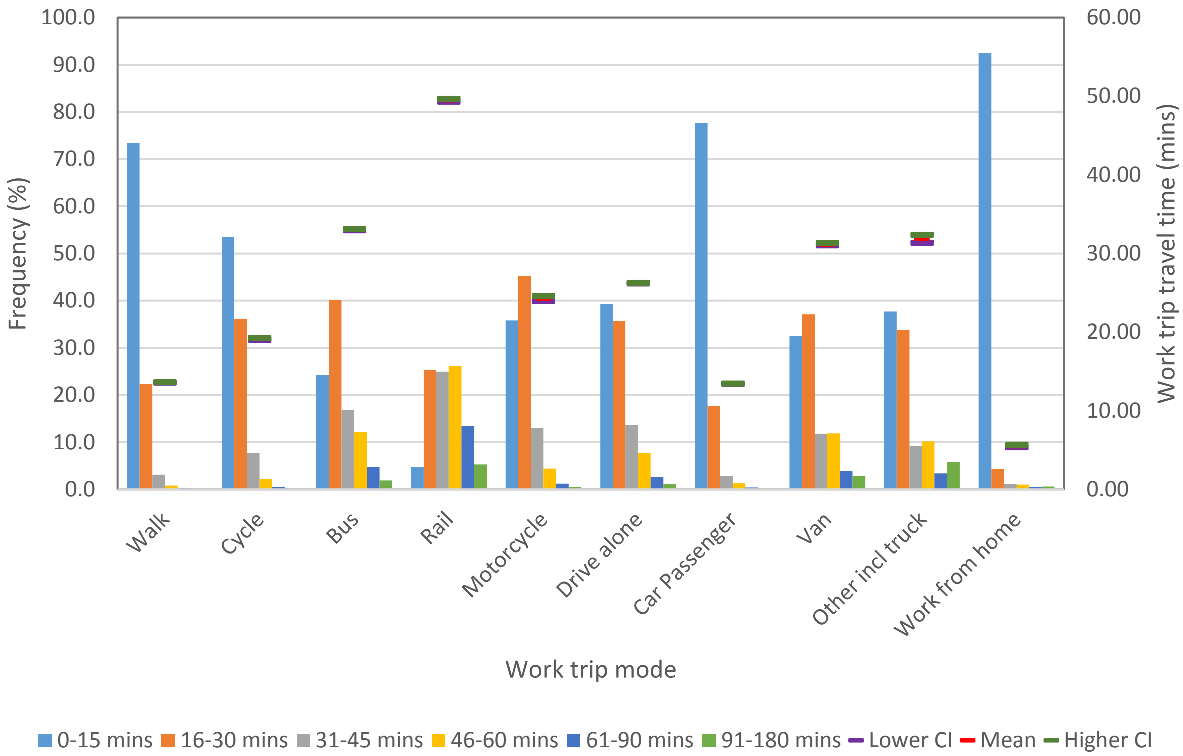

FIGURE 8 Frequency distribution and comparison of means for work trip travel time by work trip mode

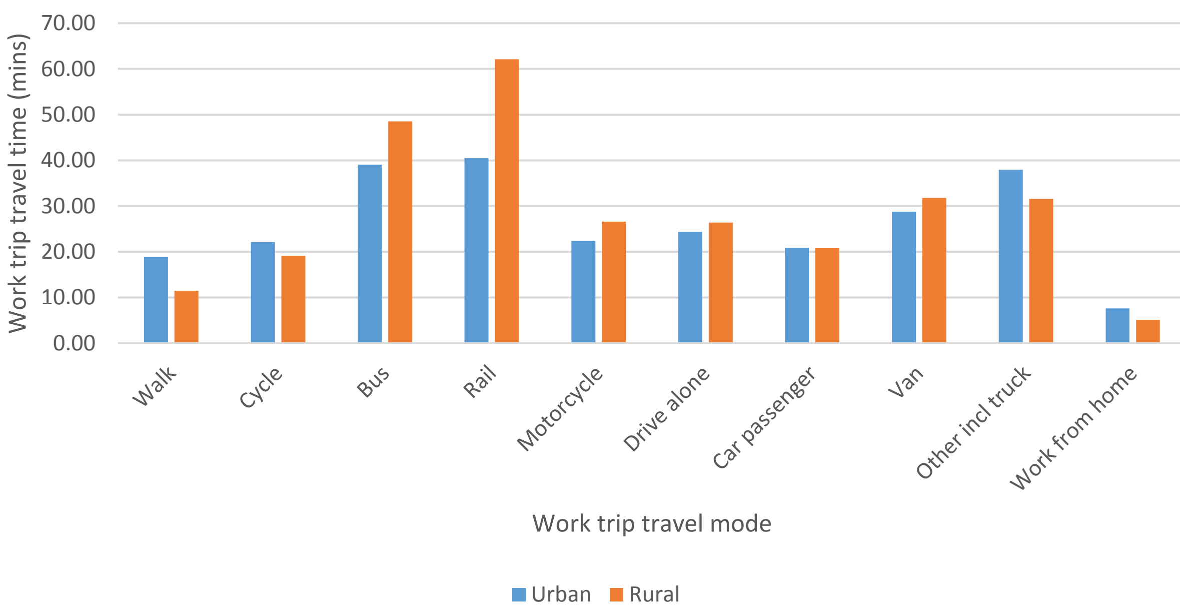

FIGURE 9 Means of work trip travel time for urban and rural based trips by work trip mode

Multinomial Logistic Regression Results

A multinomial logistic regression (MNL) analysis was set up with mode of travel as the dependent variable and gender, household composition, age, work trip travel time and industrial group as independent variables. Variable definition and frequencies are presented in Table 1.

TABLE 1 Variable definition and frequencies

Variable definition		N	%	Notes
Mode of travel	**Walk**	148,851	10.1%	-
	Cycle	36,044	2.5%	-
	Bus	81,832	5.6%	-
	Rail	48,651	3.3%	-
	Motorcycle	7,613	.5%	-
	Drive alone	951,643	64.9%	-
	Car Passenger	61,877	4.2%	-
	Van	96,253	6.6%	-
	Other incl truck	10,907	.7%	-
	Work from home	23,335	1.6%	Reference category
Gender	**Female**	718,887	49.0%	-
	Male	748,119	51.0%	Reference category
Household composition	**Single Person**	127,184	8.7%	-
	Lone parent, at least one resident child aged <=19	71,542	4.9%	-
	Lone parent with resident children but none <=19	52,828	3.6%	-
	Couple with at least one resident child aged <=19	640,217	43.6%	-
	Couple, resident children but none <=19	153,928	10.5%	-
	Couple, no resident children	251,035	17.1%	-
	Other Households	170,272	11.6%	Reference category
Age group (years)	**15-24**	109,809	7.5%	
	25-29	214,404	14.6%	
	30-39	483,158	32.9%	
	40-49	382,775	26.1%	
	50+	276,860	18.9%	Reference category
Work trip travel time (mins)	**0-15**	591,327	40.3%	
	16-30	497,824	33.9%	
	31-45	191,114	13.0%	
	46-60	123,034	8.4%	
	61-90	44,599	3.0%	
	91-180	19,108	1.3%	Reference category
Industrial group	**Not declared**	43,410	3.0%	
	Agriculture, forestry, fishing	43,622	3.0%	
	Manufacturing	184,651	12.6%	
	Construction	70,515	4.8%	
	Wholesale, Retail Trade,	377,499	25.7%	
	ICT, Financial, Professional	277,871	18.9%	
	Public Administration	97,408	6.6%	
	Education, Health etc	314,238	21.4%	
	Other Service Activities	57,792	3.9%	Reference category
Total		1,467,006	100.0%	

The model fitting information from the MNL regression are presented in Table 2. The Nagelkerke R^2 value of 0.383 represents relatively decent sized effects *(12)* and the table shows that all of the variables included are significant. The reduction in the -2 log likelihood value for the final model with the independent variables included compared with a model without them is another indicator that the model improves with their addition. The larger the chi-square value, the greater the loss of the model fit if that variable was dropped. In this case, dropping work trip travel time would result in the greatest loss of model fit followed by industrial group, gender, household composition and age group in that order.

Another useful measure to assess the utility of the model is classification accuracy which compares the predicted group membership based on the logistic model with the actual. The benchmark used here is that the model is considered useful if it shows a 25% improvement over the rate of accuracy achievable by chance alone. The proportional by chance accuracy was computed by calculating the proportion of cases for each group based on the number of cases in each group for the dependent variable in Table 1 and then squaring and summing the proportion of cases in each group; the result of which was calculated to be 0.44. The proportional by chance accuracy criteria therefore = 1.25*0.44 = 54%. The classification accuracy rate from the model was calculated to be 65.5% indicating that the model can be characterised as useful.

TABLE 2 Model fitting information and statistical significance of independent variables

Model Fitting Information				
	Model Fitting Criteria	**Likelihood Ratio Tests**		
Model	**-2 Log Likelihood**	**Chi-Square**	**df**	**Sig.**
Intercept Only	786,718			
Final	142,522	644,196	216	0.000
Nagelkerke R^2	0.383			
Likelihood Ratio Tests				
	Model Fitting Criteria	**Likelihood Ratio Tests**		
Effect	**-2 Log Likelihood of Reduced Model**	**Chi-Square**	**df**	**Sig.**
Intercept	142,522	-	0	
Gender	229,540	87,019	9	0.000
Household composition	200,779	58,258	54	0.000
Age group	172,339	29,817	36	0.000
Work trip travel time	324,352	181,830	45	0.000
Industrial group	303,190	160,668	72	0.000

The results of the logistic regression model are presented in Table 3. The model examines the factors that impact on mode choice and provides interesting insights into the impact of the independent variables on mode choice for work trips. The value of -1.505 against females in the first section indicates that they are less likely to use motorcycles to go to work than their counterparts in the working from home category (reference situation). In the case of household composition, motorcycle work trip users are least likely to be from households of couples with young children (-0.52) but interestingly bus users are even less likely to be from this group (-1.56). As might be expected, individuals in younger age groups show a higher likelihood to use motorcycles and the likelihood drops as age increases (1.03 and 1.16, respectively) but this tendency is not exclusive to the motorcycle group. Not all of the B coefficients for work trip travel time are statistically significant but of those that are motorcycle work trips are more likely to be in the 16-30 min (2.73) and 31-45 min (2.66) journey time categories rather than in the longer categories and these large positive coefficients are the largest across the modes indicating a strong relationship in this aspect. In terms of industrial group membership, motorcycle users are least likely to work in the agricultural/forestry/fishing industries (-3.8) and most likely to work in public administration or similar profession and education/health sectors.

TABLE 3 MNL Parameter estimates

Variable		Bus		Rail		Motorcycle		Drive alone		Car passenger	
		B	Std. Error	B	Std. Error	B	Std. Error	B	Std. Error	B	Std. Error
	Intercept	3.096	.102	2.674	.104	-1.505	.215	3.506	.098	.389	.111
Sex	Female	0.7**	0.019	0.48**	0.02	-1.64**	0.04	0.44**	0.017	1.0**	0.0193
	Male	0b		0b		0b		0b		0b	
Household composition	Single Person	-0.58**	0.039	-0.43**	0.041	-0.19**	0.062	0.029	0.036	-0.99**	0.0426
	Lone parent, at least one resident child aged <=19	-0.34**	0.059	-0.56**	0.064	0.03	0.107	0.55**	0.056	-0.22**	0.0597
	Lone parent with resident children but none <=19	-0.53**	0.048	-0.76**	0.053	-0.24**	0.083	-0.07	0.044	-0.38**	0.0491
	Couple with at least one resident child aged <=19	-1.56**	0.031	-1.12**	0.033	-0.52**	0.048	-0.04	0.029	-0.6**	0.0316
	Couple, resident children but none <=19	-1.01**	0.0371	-0.84**	0.04	-0.39**	0.062	-0.017	0.035	-0.29**	0.0374
	Couple, no resident children	-0.97**	0.035	-0.56**	0.036	-0.26**	0.054	-0.023	0.033	-0.32**	0.0355
	Other Households	0b		0b		0b		0b		0b	
Age group (yrs)	15-24	2.30**	.047	2.1**	.050	1.03**	.077	1.22**	.045	2.49**	.047
	25-29	1.71**	.037	1.83**	.039	1.16**	.057	1.3**	.034	1.69**	.037
	30-39	0.68**	.023	0.91**	.025	0.73**	.040	0.62**	.020	0.65**	.023
	40-49	0.11**	.023	0.24**	.026	0.51**	.040	0.19**	.019	.035	.023
	50+	0b		0b		0b		0b		0b	
Work trip travel time (mins)	0-15	-4.05**	0.091	-5.3**	0.093	-0.32	0.198	-1.43**	0.088	-0.89**	0.0996
	16-30	-0.012	0.095	-0.7**	0.095	2.73**	0.2	1.33**	0.093	1.40**	0.1043
	31-45	0.9**	0.108	0.5**	0.108	2.66**	0.208	1.59**	0.106	1.30**	0.1167
	46-60	1.1**	0.11	0.82**	0.11	1.73**	0.214	1.23**	0.108	1.0**	0.1192
	61-90	1	0.132	0.98**	0.132	1.12**	0.244	0.96**	0.13	0.76**	0.142
	91-180	0b		0b		0b		0b		0b	
Industrial group	Not declared	0.16**	0.054	-0.35**	0.063	-0.32**	0.106	-0.14**	0.049	0.41**	0.0556
	Agriculture, forestry, fishing	-3.9**	0.076	-5.**	0.17	-3.8**	0.15	-2.33**	0.035	-1.87**	0.0474
	Manufacturing	0.07	0.047	-0.02	0.053	0.64**	0.081	1.11**	0.042	1.47**	0.0467
	Construction	-0.9**	0.063	-1.33**	0.074	-0.62**	0.109	0.23**	0.053	0.8**	0.0598
	Wholesale, Retail Trade	0.96**	0.04	0.5**	0.045	0.7**	0.075	0.88**	0.036	1.08**	0.0412
	ICT, Financial, Professional	0.08	0.039	0.65**	0.043	0.097	0.074	-0.22**	0.035	-0.22**	0.0411
	Public Administration	1.8**	0.073	2.08**	0.076	2.2**	0.1	2.01**	0.07	1.76**	0.075
	Education, Health etc	1.08**	0.046	0.99**	0.05	1.45**	0.081	1.63**	0.042	1.36**	0.0468
	Other Service Activities	0b		0b		0b		0b		0b	

Notes: Reference category is working from home

** means statistically significant at 0.01 level

CONCLUSIONS

In the context of rising demand for more flexible modes, the paper seeks to understand the user profiles of motorcycles for the work trip in the context of census data derived variables. The results were made up of two parts 1) modal comparisons of variable frequency distributions and 2) results from a multinomial logistic regression analysis with mode of travel as dependent variable and a number of socio-economic and work trip characteristics as independent variables.

The frequency distribution results show a high degree of similarity, and in most cases statistically significant similarity, between the motorcycle group and single occupancy car trip groups when comparing the following: number of persons in households, number of students in household, household composition, age, socio-economic group and work trip travel time. In the case of gender, the motorcycle group tends to be similar to the van and other including truck group with a much higher number of males than females in those groups.

The multinomial logistic regression model found the independent variables made statistically significant contributions to the model improving its classification accuracy significantly over what would be achieved by chance. The chi-squared values indicated that dropping work trip travel time would result in the greatest loss of model fit followed by industrial group, gender, household composition and age group, in that order.

The model indicates motorcycle work trip users are least likely to be from households of couples with young children and, as might be expected, individuals in younger age groups show a higher likelihood to use motorcycles and the likelihood drops as age increases but this tendency is not exclusive to the motorcycle group. Motorcycle work trips are more likely to be in the 16-30 min and 31-45 mins journey time categories rather than in the longer categories and these large positive coefficients are the largest across the modes indicating a strong relationship in this aspect. In terms of industrial group membership, motorcycle users are least likely to work in the agricultural/forestry/fishing industries and most likely to work in public administration or similar profession and in the education/health sectors.

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