BEHAVIOUR AND PERCEPTIONS OF POWERED TWO-WHEELER USERS IN STREET DESIGNS WITH ELEMENTS OF SHARED SPACE

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ABSTRACT

Inspired by developments in urban planning, the concept of "shared space" has recently emerged as a way of creating a better public realm by facilitating pedestrian movement and lowering vehicle traffic volumes and speeds. Previous research looked at how the behaviour and perceptions of pedestrians, vehicle drivers and pedal cyclists, vary with the introduction of elements of shared space. The aim of this study is to extend this analysis to Powered Two-Wheeler (PTW) riders, who are a road user group that is often overlooked. The study consists of two parts. The first one conducts a video observation analysis of the behaviour of PTW riders before and after the redevelopment of the Exhibition Road site in London's South Kensington area to a layout with shared space elements, and looks at changes in key variables, such as flow and speed. The second part, then, provides an insight into the perceptions of PTW riders through a generic stated-preference survey investigating their "willingness to share space" with vehicles and pedestrians. The results show that PTW riders appear to treat shared space features more like motorised users rather than non-motorised ones. Indeed, lower PTW flows and speeds and fewer overtaking manoeuvres are recorded on Exhibition Road post-redevelopment, while lower willingness to share is expressed when large numbers of pedestrians and static obstacles (such as trees, seating and fountains) are present. On the other hand, PTW riders are more positive towards shared space elements if the design provides ample space and a smooth pavement surface.

1 INTRODUCTION

The concept of shared space has emerged as part of a continuous trend over many years towards a more integrated approach to the design of urban streets. Inspired by advances in urban planning, it revolves around layouts aimed at asserting the function of streets as places rather than as arteries, which involves designing for easier pedestrian movement and lower vehicle speeds (Figure 1). As such, it contrasts the traditional car-oriented approach that drove the design of streets for many decades, which relied upon the segregation of motorised traffic from other road users in order to ensure unobstructed flows (*1*).

An important issue needing clarification here is the definition of the term "shared space", whose purpose is not to classify entire streets using the binary characterisation of "shared" or "not shared". Instead, the term is used to collectively refer to a set of context-sensitive design treatments, whose aim is to create a more pedestrian-friendly environment, and whose extent of implementation may vary. Such treatments range from "light-touch" solutions, such as the replacement of "formal" zebra or signal-controlled crossing facilities with more "informal" (uncontrolled) pedestrian crossings, to more radically-engineered layouts involving level surfaces in so-called "naked streets", where most, or even all, delineation between pedestrian and vehicle areas is removed (*2-5*). Examples of streets with varying extents of shared space features can be found around the world and include: "woonerf" and "home zone" streets in residential areas in the Netherlands and UK respectively; the "Manual for Streets" approach in the UK (*6-7*); and the "Complete Streets" initiative in the USA (*8*).

[Figure 1 here]

Shared space has been analysed fairly extensively in recent years, yet the focus has been almost exclusively on pedestrians and vehicle drivers, and to a lesser extent on pedal cyclists. The important group of Powered Two-Wheeler (PTW) users has so far remained largely under-represented, despite the unpredictable stance that its interaction with shared space features may exhibit. Namely, as motorised users, PTW riders (a.k.a. motorcyclists) may wish to maintain high travel speeds and may hence feel uncomfortable riding on streets with elements of shared space. On the other hand, however, as more vulnerable than car drivers, they may favour the "calmer" traffic conditions created by the shared space features.

It is therefore important to investigate the behaviour and perceptions of PTW riders towards shared space, and it is the aim of the present study to identify and quantify the factors that influence these. The work complements previous research on the topic, which covered a wide range of shared-space-related topics, such as pedestrian-vehicle traffic conflicts (*9-10*) and behavioural interactions (*11*), pedestrian and pedal cyclist perceptions (*12-13*), pedestrian and driver willingness to share (*14*), and pedestrian gap acceptance behaviour (*15*).

The present study consists of two parts. The first part analyses the behaviour of PTW riders before and after the implementation of shared space features and looks at changes in key variables, such as PTW average speed and flow, as well as at other aspects, such as overtaking behaviour. The example of Exhibition Road in London's South Kensington area is used, with data coming from video observations during periods before and after its conversion from a conventional divided roadway to a more "open" layout featuring some elements of shared space. The second part then explores PTW rider perceptions, as expressed through the riders' "willingness to share space" with other road users in relation to a number of attributes. These are identified with the help of a focus group and their importance is determined by collecting a set of responses from motorcyclists, who are presented with hypothetical scenarios in a generic (non-site-specific) stated-preference survey.

The paper is structured as follows: Section 2 gives the background of the study, by reviewing previous work on PTW rider behaviour and perceptions. Section 3 then presents the methodology adopted in the behavioural observation study, and reports and discusses the results obtained. Section 4 documents the second part of the study, relating to the methodology and analysis of the motorcyclist perceptions survey, while Section 5 draws conclusions and identifies areas of future work.

2 BACKGROUND ON PTW RIDER BEHAVIOUR AND PERCEPTIONS

In a study by Mannering and Grodsky (*16*) it has been identified that motorcycling requires a unique skillset, which includes the ability of high-level physical coordination and balance, that is similar in principle to pedal cycling, but much more demanding in terms of intensity. As such, PTW riders have in the past often been viewed as a small high-risk acceptance group, whose primary purpose for riding is to seek excitement (*17*).

However, this claim has more recently been rebutted, as official statistics have shown that a large proportion of PTWs are used for non-leisure travel. For instance, according to the UK Department for Transport's (DfT) latest statistical release, over half (52%) of all motorcycle mileage in England in the 2002-2016 period was carried out for the purpose of commuting and business – significantly higher than the respective proportion for all modes combined (29%) (*18*). Indeed, most recent UK annual vehicle licencing statistics show that in 2019 there were as many as 119,000 new motorcycle registrations, which corresponded to just over 4% of all registered vehicles (*19*). It can be, hence, concluded that PTW users are not a small minority with peculiar characteristics, but rather a mainstream road user group occupying a non-trivial proportion of the modal share.

An important pitfall of motorcycling, however, is that it is widely considered the least safe transport mode. Crash statistics, unfortunately, confirm this perception as reality: according to the UK DfT's latest data, in 2019 there were over 16,000 motorcyclist casualties in Great Britain, 336 of which were fatalities. Considering the casualty and fatality rates, these were 5051 and 105 per billion passenger miles, respectively, greatly exceeding the corresponding pedal cyclist and pedestrian rates, and making PTW riders the most vulnerable road user group (*20*). Past analysis from other countries has delivered similar findings (e.g. (*21*)). As a result, much of the previous research on PTW riders has concentrated on the central issue of safety.

Findings from several decades of studies on PTW crashes have identified a number of factors that contribute to this overall poor safety record. Both the seminal "Hurt" (*22*) and "MAIDS" (*23*) reports in the US and the EU respectively found that a substantial proportion of the crashes are caused by the often dangerous riding behaviour of the motorcyclists, which may include speeding and violating right of way. More recent work further showed that many crashes occur when motorcyclists attempt to overtake other vehicles or pedestrians (*24*).

Other research demonstrated that a cause of crashes involving PTWs lies in the situational awareness of drivers and riders (*25-26*), and specifically in the absence of mutual awareness (*27*). Indeed, it has been found that, perhaps paradoxically, both drivers and PTW riders may often overlook objects and events occurring close to them and in the central foreground, as more distant objects could catch and hold their views instead (*28*). This phenomenon has been termed "inattentional blindness" (*29*), and the extent to which it occurs is variable, with the orientation, speed, size and shape of the objects in question playing an important part (*30*), along with conspicuity (*31*) and expectation (*32*).

The past research on motorcyclist crashes reveals useful behavioural and perceptual traits of PTW users, which can inform the investigation of their behaviour and perceptions towards shared space. From the review of the research, a number of factors relating to PTW rider behaviour become evident, such as the speed of riding and the overtaking behaviour. Along with the PTW traffic volume, the observation of these factors can provide useful insight into how PTW user behaviour may vary between different environments and times.

In terms of perception, elements potentially affecting PTW rider comfort and confidence can be categorised into two groups: internal elements and external elements. The former include the characteristics and attributes relating to the rider himself/herself, whereas the latter refer to the features relating to the surrounding conditions. A number of potential elements are listed below:

<u>Internal elements</u>:
- Gender
- Age
- Riding frequency
- Motorcycle type
- Trip characteristics (purpose, length etc.)

<u>External elements</u>:
- Volume of vehicle traffic
- Pedestrian density and pedestrian types (children, elderly, disabled etc.)
- Surface condition (wet/dry) and paving materials and colour
- Lighting level
- Presence of obstacles
- Street space size (length and width)

- Presence of other motorcycles
- Traffic regulations
- Presence of pedal cyclists
- Parked vehicles
- Land uses

In this study, the behaviour of PTW users before and after implementation of a new street design with shared space features is first investigated using videos. Then, the degree to which different factors may influence the willingness of PTW users to share space is investigated by means of a stated-preference survey. The methods followed and results obtained are reported in the next two sections.

3 PTW USER BEHAVIOURAL OBSERVATION STUDY

The first part of the present study deals with the analysis of the changes in the behaviour of motorcyclists, monitored through video observation, in response to the redevelopment of the Exhibition Road site to a layout with elements of shared space. This section describes the study area and the conduct of the video observations, and presents the results obtained.

3.1 Study area and observation methodology

Exhibition Road is an 800 m long road located in the Royal Borough of Kensington and Chelsea (RBKC) in London and is home to a number of London's most popular museums (Natural History, Science, V&A). The surrounding area of South Kensington is well-known as a cultural centre, including other venues such as the Royal Albert Hall as well as many academic institutions, such as Imperial College London. As the previous conventional divided roadway layout of Exhibition Road was crowded (a problem exacerbated by numerous pedestrian barriers) and dominated by high traffic flows and parked vehicles, the RBKC undertook an engineering scheme, the "Exhibition Road Project", which included its redevelopment featuring a number of elements of shared space (Figure 2).

[Figure 2 here]

The scheme was implemented over four years from mid-2008 to completion in late 2011. It comprised the following three main traffic management changes:

1. Re-allocation of street space (Figure 2a): The previous layout of the 24 m wide Exhibition Road consisted of a 16 m wide dual carriageway, accommodating one lane of traffic in each direction as well as excess width allocated to parked vehicles, and of two 4 m wide footpaths on either side of the carriageway, accommodating pedestrians. As a result of the redevelopment, traffic was shifted to the eastern side of the road to occupy a single carriageway of 8 m width (termed the "traffic zone"), with the former western side of the dual carriageway becoming a so-called "transition zone", accommodating primarily pedestrians, but also parking, cycles and coaches alighting to drop-off or pick-up passengers. The two 4 m footpaths remained in place and formed the so-called "pedestrian zone". The space also saw the removal of the kerbs and the implementation of an end-to-end single surface with an 800mm corduroy tactile delineator to indicate the start of the pedestrian zone on each side of the road.
2. Unravelling of a one-way system (Figure 2b and 2c): In the original layout, a one-way system was in place around the South Kensington Station area, whereby the southbound traffic was led along the southern tip of Exhibition Road and along Thurloe Street, while the northbound traffic was guided along Thurloe Place. As a result of the redevelopment, Thurloe Place was converted

to a two-way street, accommodating both the northbound and the southbound traffic, while Thurloe Street was converted to an access-only street.

3. Re-design of pedestrian crossing facilities (Figure 2d): At the intersection of Exhibition Road with Cromwell Road, the original design included a staggered north-south pedestrian crossing on the western side of the site, which, however was not following the desire-lines and required pedestrians to cross in two stages, thus resulting in a high number of jaywalkers. The redevelopment removed the staggered crossing and replaced it with a wide (12 m) straight-across crossing, allowing pedestrians to complete their crossing in a single phase. The scheme also included the removal of pedestrian guardrails and other street clutter to further facilitate pedestrian movement. Some vehicle movements were also prohibited.

In order to assess the impact of the new design of Exhibition Road on a wide range of aspects, including PTW rider behaviour, video footage has been collected for periods before and after the implementation of the scheme. In the before-case, video has been collected in August 2008, prior to the start of the redevelopment works, through high-mast cameras installed at a number of critical locations. For the after-situation, video has been recorded at the same locations for periods between October and December 2011, following the completion of the scheme. The locations monitored in the present study and dealing with investigating PTW user behaviour are (Figure 3): the main body of Exhibition Road, covered by Camera B in the before- and Camera 6 in the after-videos (Location L1); the junction with Cromwell Road (Location L2 – Camera D before, and Camera F after); and Thurloe Street (Location L3 – Camera F before and Camera 1 after).

[Figure 3 here]

For the timeframe observed in the videos, a typical working day with dry weather is considered. To allow sufficient time for commuters to be observed, a timeframe starting at 8 am and ending at 6 pm is selected for the observation. This provides 10 hours of observed footage for each camera, resulting in a total of 30 hours of footage before and 20 hours of footage after the scheme has been implemented. The days and dates chosen for each camera, as well as the duration of the survey are, hence, presented in Table 1.

[Table 1 here]

As regards the individual behavioural attributes observed in the videos, and based on the review of the background, the PTW flow before and after the scheme is the most important behavioural component enabling the investigation of whether the new layout attracts or deters motorcyclists. The scheme has as its core objective to reduce the speeds and flows of motorised vehicles, and hence it is expected that overall there are also fewer PTWs, but a case for the contrary can also be made, given that motorcyclists may find the calmer traffic conditions attractive. The flows are counted hourly to show how the flow trend varies during the day, which gives a good insight into the types of motorcyclists in the area before and after redevelopment. Namely, since the majority of motorcyclist commuter trips are likely to be concentrated in the mornings and evenings, any changes in the morning and evening flows can be assumed to be attributed mainly to the behaviour of commuters. On the other hand, motorcyclist leisure trips are likely to be more evenly distributed throughout the day and to make up a greater proportion of the total motorcyclist trips at times outside the mornings and evenings, so flow changes in those times can be assumed to be attributed mainly to the behaviour of leisure riders.

Aside of the flows, the speeds of PTWs are measured before and after to investigate if there are any changes as a result of the redevelopment. After-speeds are measured only in the vehicle zone, where PTWs are expected to be located. On one hand, PTWs should be able to travel at higher speeds due to the reduction in vehicle traffic flow, but on the other hand, the removal of the kerb and guardrails may mean that there will be a higher degree of interaction with pedestrians and other road users, and hence lower speeds. The speed analysis will, thus, give an indication on whether the reduced flow or the increased interaction has a greater impact. In addition, the hourly average speeds provide information on which type of motorcyclists travel faster; high speeds in the morning and evening relative to the rest of the day could indicate that commuters travel faster than other motorcyclists.

Finally, the third attribute to be monitored is the PTW overtaking behaviour, and specifically the number of overtaking manoeuvres. As identified in the background section, many PTW crashes occur during overtaking, and as such the change in overtaking behaviour before and after the redevelopment may indicate how comfortable/confident PTW riders are in the space. On one hand, the reduction in vehicle traffic flow may result in motorcyclists feeling more confident, which may translate to higher numbers of overtaking manoeuvres. On the other hand, however, the increased interaction with other road users facilitated by the design may make motorcyclists more cautious and alert, and hence more reluctant to overtake other vehicles. As with flow and speed, the hourly breakdown of overtaking occurrences gives a good insight into the types of motorcyclists involved, i.e. commuters or not.

3.2 Results

Table 2 presents, the average and peak flows, and the average and standard deviation of the speeds, of PTWs at the three examined locations before and after the redevelopment. The data show statistically significant (at the 0.05 level) drops in the average and peak flows of motorcyclists on Exhibition Road (L1) of 68% and 75% respectively. It is hence suggested that fewer motorcyclists have been attracted to Exhibition Road post-redevelopment. At Thurloe Street (L3) motorcyclist flows have reduced to almost zero. This is expected, as the site has been converted to an access-only road, and has therefore ceased to act as a thoroughfare for motorised traffic, including PTWs. At Cromwell Road, on the other hand, there is no statistically significant change of PTW average or peak hourly flows. This is also expected, as apart from the pedestrian crossing of Exhibition Road the layout has not changed. These trends are similar to the ones for motorised traffic at the three locations, as reported in previous studies (*10-11*).

It is important to note here that the "before" videos have been collected in August, when schools and universities are shut, whereas the "after" videos have been collected in October-December, when the educational establishments are open in the area. This may have had an influence on the PTW flows, and the hourly flows of PTWs on Exhibition Road (L1) before and after the redevelopment seem to support this finding; as can be noted in the top-left graph of Figure 4, there are greater drops in the number of PTWs between 8 am and 9 am and between 4 pm and 6 pm than in other periods. This may suggest that the new layout has particularly deterred commuter motorcyclists from using Exhibition Road, but also that part of the reduction may be due to seasonal variation. Due to data availability constraints it is not possible to perform an in-depth analysis in order to accurately measure the magnitude of the seasonal variation effect, and this is a limitation of the present study. Nevertheless, it can be noted that the hourly PTW flow profile of Cromwell Road (L2) does not show statistically significant differences between the pre- and the post-redevelopment case, which suggests that the effects of seasonal variation are minor.

[Table 2 here]

[Figure 4 here]

Looking at the speeds of the PTWs before and after the redevelopment, it is evident that these are lower in the after-situation at L1 and L3 (statistically significant to the 0.05-level). It may be, hence, deduced that the increased level of sharing introduced by the redevelopment has affected motorcyclists in the same way as vehicle drivers by making them ride slower. As expected, on the other hand, given then very few modifications at L2, no statistically significant changes in PTW speeds are reported. Moreover, no statistically significant changes are reported with respect to the variability of the speeds (expressed by the coefficient of variation (COV) of speed, i.e. standard deviation over average), which suggests that speeds have decreased as a whole and their composition has remained unchanged. No significant changes are reported in the hourly variation of speed either, which suggests that speeds are consistent between commuter and other motorcyclists.

Looking at the overtaking behaviour, this is only analysed along the main body of Exhibition Road (L1), as due to the road geometry no overtaking occurrences are observed at either the Cromwell Road junction (L2) or Thurloe Street (L3) before or after redevelopment. Throughout the whole observation period a statistically significant (at the 0.05 level) 81% drop in the total number of PTW overtaking manoeuvres is reported post-redevelopment, from 135 to 26. This suggests that, in line with the reductions in flows and speeds, the redevelopment (which has introduced lane narrowing and greater interaction with other modes) has made motorcyclists more cautious and hence less willing to overtake other slower or stopped vehicles.

The hourly variation of the overtaking occurrences (Figure 5) shows that this is mostly evident in the afternoon peak periods: specifically, the higher vehicle traffic volumes on Exhibition Road before redevelopment in the 4 pm and 5 pm periods resulted in cars forming queues, and the generous road width allowed PTWs to overtake them; this phenomenon no longer occurs post-redevelopment, however, partly due to the less generous geometry, but also due to the lower vehicle traffic flows. Given that overtaking is an important source of PTW crashes, this can be considered a safety benefit of the redevelopment.

[Figure 5 here]

All in all, based on the observations carried out around the Exhibition Road site, it can be concluded that PTW users have responded to the redevelopment similarly to motorised vehicle drivers (i.e. reduced flows and speeds, and less aggressive behaviour) rather than as pedestrians or cyclists (*11-15*). As such, from the point of view of shared space, PTWs can be viewed more as motorised users and less as non-motorised ones.

4 STATED-PREFERENCE SURVEY ON PTW USER PERCEPTIONS

Supported by the behavioural analysis of the previous section, the second part of the study investigates the perceptions of motorcyclists by means of a stated-preference survey. The analysis gives an insight of the degree to which different person-specific (internal) and street-design-specific (external) factors may influence the willingness of PTW users to share the space with others, and the survey design and results obtained are outlined in this section.

4.1 Survey design and responses

The first step of the survey design includes defining the target sample of respondents; as motorcyclists of all age groups and experience can use a street with elements of shared space, the target sample involves all motorcyclists. Hence, it has been decided to conduct the study as a web-based survey in order to get as diverse a sample as possible. Regarding dissemination, the survey has been setup using the University of Southampton's "iSurvey" tool (https://www.isurvey.soton.ac.uk) and has been circulated to potential respondents through email lists and word of mouth.

The actual choice attributes and levels in the context of PTW users' willingness to share space need to be determined before surveying. As a result of a focus group consisting of staff and students from the University of Southampton, the list of external attributes given in Section 2 has been refined down to seven bi-level attributes included in the final survey. The attributes chosen and their corresponding levels are presented in Table 3.

[Table 3 here]

[Figure 6 here]

The main part of the study is carried out in the form of a stated-preference survey, whereby each respondent is presented with a set of scenarios, i.e. combinations of selected attributes (and corresponding levels), to which he/she is asked to make a decision on whether he/she, as a rider on their motorcycle, would be willing to ride their motorcycle along the street and share the space with other road users. Each scenario consists of all seven attributes with a specific level for each attribute (Figure 6). The survey also includes questions on the respondent's age, gender, riding frequency, and motorcycle type, in order to define his/her characteristics. An introductory description of the concept shared space is also provided at the beginning of the survey to help set the context.

An issue that needs to be dealt with is the number of questions that the respondent would be presented with, as the seven attributes chosen with two levels each would result in a total of 2^7=128 scenarios. In line with previous relevant work on the topic (*14*), a fractional factorial design is applied in order to reduce the number of scenarios without losing important information. For the survey on the PTW users' willingness to share space, a 1/16 fractional factorial design is used, which results in 128 / 16 = 8 questions. This is done following the method described in (*33*), which involves obtaining the full factorial (all combinations) for the first three most important factors (identified by the focus group) and then selecting certain levels for the remaining four factors by simple multiplication of the levels for the initial three factors, so as to confound some main effects' estimates with the estimates of the interaction effects of the initial three factors. The following three factors have been identified by the focus group as most important: pedestrian density, space size, and obstacles. It should be noted that a Resolution III design has been sought, i.e. one where main effects are not confounded with each other and can be estimated adequately reliably.

The procedure of factorial design used (Table 4) has been adapted from suggested summary tables in the literature (*34-35*). As such, the levels chosen for Factor 4 for each scenario are determined by multiplying the levels of Factors 1 and 2; similarly Factor 5 is formed using Factors 1 and 3, Factor 6 is formed using Factors 2 and 3, and Factor 7 is formed using Factors 1, 2 and 3. An important consideration here is the fact that '+1' denotes the levels of PD – "not many", SS – "big", OB – "few", SC – "smooth", LL – "good", VT – "not many" and MT – "few", whereas '-1' denotes PD – "many", SS – "small", OB – "several", SC – "rough", LL – "low", VT – "many" and MT – "several".

[Table 4 here]

It should also be mentioned that the order in which the scenarios appear to the respondent has been randomised in order to reduce the occurrence of biases towards particular factor combinations.

Considering the response, a medium-sized sample has been obtained, consisting of 39 usable responses. These correspond to a set of 302 individual scenarios used in the analysis (2 respondents have not provided answers to all scenarios), out of which 148 (49%) have been 'Yes' responses. With respect to the demographics of the sample of the usable responses:

- 27 of the 39 respondents are male, while 12 are female.
- 14 respondents are under 30 years old, 16 are between 30 and 49 and 9 are over 50.
- 27 respondents identify as frequent riders, i.e. riding a motorcycle at least once a week, while 12 are infrequent riders, i.e. riding up to once a month.
- 29 respondents ride a big motorcycle (i.e. cruiser, sport bike or touring bike), while 10 ride a smaller one (i.e. scooter/moped).

The number of 'Yes' and 'No' responses received for each of the eight scenarios of the survey are shown in Table 5.

[Table 5 here]

4.2 Analysis and modelling

In order to interpret the results and fit a model to determine how each of the factors affects the PTW users' willingness to share space, binary logistic regression is performed. Following (*36*), a binary logistic regression model is defined as:

$$Y_i = \ln(P_i/(1-P_i)) = \beta_0 + \beta_1 \cdot X_{1,i} + \beta_2 \cdot X_{2,i} + \ldots + \beta_K \cdot X_{K,i}$$

where Y_i is the dependent variable, which is equal to the logit transformation of the probability P_i of the presence of a certain resulting outcome or condition that is usually denoted using a binary indicator variable coded as 1 or 0, β_0 is the model constant, and $\beta_1, \ldots, \beta_K$ are the unknown parameters corresponding with the explanatory independent variables (X_k, $k = 1, \ldots, K$), i.e. the model attributes. The unknown parameters are typically estimated using maximum likelihood methods, and once estimated, they can be used to estimate the probability that the outcome takes the value 1 as a function of the model attributes.

In this study, the outcome of the model is the probability of a PTW rider willing to share the space with vehicles and pedestrians (SHARE, yes = 1, no = 0). The set of model attributes includes those relating to each scenario, as well as those relating to the respondent's characteristics, as stated at the beginning of the survey.

Namely, the scenario-specific (external) attributes are the ones shown in Table 3, i.e. pedestrians (PD, not many = 0, many = 1), space size (SS, small = 0, big = 1), obstacles (OB, few = 0, several = 1), surface condition (SC, rough = 0, smooth = 1), lighting level (LL, low = 0, good = 1), vehicles (VT, not many = 0, many = 1) and motorcycles (MT, few = 0, several = 1). Similarly, the respondent-specific (internal) variables are: gender (GEN, female = 0, male = 1), age (AGE, under 30 years = 0, 30-49 years = 1, over 50 years = 2), riding frequency (FRQ, occasionally = 0, frequently = 1) and motorcycle type (MTP, small = 0, big = 1).

The SPSS 25 statistical software package is used to perform the binary logistic regression and estimate the coefficients of the resulting logit model. Observing the data input, most of the independent variables (internal and external) are binary, with the exception of the respondent's age, which is categorical. As such, considering the fact that the number of variables coming into the model for each attribute should be n-1, n being the number of levels, each attribute will have one variable in the model, and the AGE attribute will have two. Hence, the following binary variables are generated: the dependent variable Y_{SHARE_1} , which is equal to the logit transformation of the probability of the PTW rider willing to share space with vehicles and pedestrians (i.e. SHARE = 1), P_{SHARE_1}, and the independent variables *GEN_1*,

AGE_1, *AGE_2*, *FRQ_1*, *MTP_1*, *PD_1*, *SS_1*, *OB_1*, *SC_1*, *LL_1*, *VT_1* and *MT_1* (for GEN = 1, AGE = 2, AGE = 3, FRQ = 1, MTP = 1, PD = 1, etc.). The model is thus of the form:

$$Y_{SHARE\_1} = \ln(P_{SHARE\_1}/(1 - P_{SHARE\_1})) = \beta_0 + \beta_1 \cdot (GEN\_1) + \beta_2 \cdot (AGE\_1) + \beta_3 \cdot (AGE\_2) + \beta_4 \cdot (FRQ\_1) + \beta_5 \cdot (MTP\_1) + \beta_6 \cdot (PD\_1) + \beta_7 \cdot (SS\_1) + \beta_8 \cdot (OB\_1) + \beta_9 \cdot (SC\_1) + \beta_{10} \cdot (LL\_1) + \beta_{11} \cdot (VT\_1) + \beta_{12} \cdot (MT\_1).$$

The results of the binary logistic regression are shown in Table 6. As can be seen, the model as a whole is statistically significant as the null hypothesis that the model does not estimate the data correctly is rejected
(chi^2 = 94.228; Sig. = .000). Additionally, it can be seen that the model is a good fit, as the null hypothesis that the model does not fit the data accurately is rejected at the 5% level in the Hosmer–Lemeshow test (chi^2 = 8.779; Sig. = .361). Furthermore, the potential presence of multicollinearity is investigated by fitting a multiple linear regression model to the data and calculating the Variance Inflation Factor (VIF) measure for each of the independent variables. As the highest VIF value among all independent variables is found to be 1.622, which is lower that the usually adopted threshold (10), it can be concluded that no significant multicollinearity exists.

[Table 6 here]

Considering the coefficients of the binary logistic regression model in Table 6, it can be first observed that the constant term of the model is statistically significant at the 0.05 level (since the "significance" value is lower than 0.05), and that it has a negative value. This indicates that PTW users appear to have an initial unfavourable view towards the idea of sharing space with pedestrians and vehicles, and it remains to be seen whether, according to the survey carried out, the presence of certain features and circumstances can "swing" a PTW user's opinion towards a more favourable position.

Looking at the coefficients of the scenario-specific variables, it can be seen that high numbers of pedestrians and the presence of several obstacles have negative statistically significant effects on the willingness of motorcyclists to share space with pedestrians and other vehicles. On the other hand, riding through a big street space (in terms of length and width), or on a street that has a smooth surface, both have positive statistically significant effects. These all seem fairly reasonable. Namely, the presence of obstacles (e.g. trees, seating, fountains etc.) can severely obstruct the path of PTWs and may contribute to a negative riding experience; if, additionally, these obstacles are moving (i.e. pedestrians), then PTW riders would naturally feel more uncomfortable, as they would need to devote extra caution to their surroundings. On the other hand, a big space and a smooth street surface (with fewer potholes, bumps etc.) may enhance the riding experience and compensate for any potential discomfort caused by elements of shared space.

Considering the coefficients of the respondent-specific attributes, it can be observed that the variable relating to riding a big motorcycle type has a positive statistically significant coefficient. While unexpected, this finding is reasonable, as it points to the conclusion that, under the condition of increased interaction with other road users, riding a large motorcycle asserts the presence of the rider in the street and makes them feel more confident and comfortable than they would be if they were riding a smaller motorcycle.

Finally, it is noted that a number of model variables do not have statistically significant coefficients. This, however, does not necessarily mean that they do not influence the willingness to share of PTW users, as they may be confounded with other attributes when two-way and three-way interaction terms are added to the model. To investigate these, however, a minimum Resolution IV fractional factorial design would have been required, which would have increased the number of questions of the survey to impractical levels and would have, hence, limited the response rate. Alternative ways could be considered in this case, but such analysis lies beyond the scope of this study.

All in all, and supporting the same conclusion of the first part of the study, it appears that the perception of PTW riders towards shared space is closer to that of vehicle drivers rather than to that of pedestrians or pedal cyclists. Indeed, the results suggest that motorcyclists behave more like motorised users and less like vulnerable ones, as they mostly favour having relatively unobstructed passage through a road on a motorcycle that best asserts their presence and are not attracted by the "calmer" traffic conditions. Providing ample space and a smooth surface is likely to be the most effective way of achieving their integration in streets with elements of shared space.

5 CONCLUSIONS

In light of the shift in focus in urban street design, this paper has conducted an investigation of the behaviour and perceptions of PTW users towards the implementation of street layouts with elements of shared space. The study has consisted of two parts. First, using the Exhibition Road site in London's South Kensington area as a case study, changes in the behaviour of motorcyclists as a result of the redevelopment to a layout with elements of shared space have been investigated by means of video observation and analysis. Then, the effect of different parameters on the motorcyclists' willingness to share space with other road users has been examined through a generic stated-preference survey.

The findings support the conjecture that PTW users perceive and behave towards shared space features more like motorised users rather than non-motorised ones. Indeed, the observation has shown that PTW traffic has "calmed down" post-redevelopment in Exhibition Road in line with motorised vehicle traffic (i.e. lower flows, lower speeds, less aggressive behaviour), while the stated-preference survey results have suggested that PTW users are generally unlikely to be willing to share the space, especially if there are many static or moving obstacles (i.e. pedestrians). Still, their willingness to share increases if features facilitating their movement are provided by the design, i.e. ample space and a smooth pavement that is free of potholes and bumps.

While the present study has thrown some light into the under-explored topic of PTW user behaviour and perceptions towards street designs with elements of shared space, research in this direction continues. For instance, a limitation of this research is that the post-redevelopment video footage used in the behavioural observation study is from late 2011, i.e. from the period immediately after the completion of the works on Exhibition Road. It is, therefore, possible that the traits captured may be affected by certain transitional effects that could have emerged as users would adapt to the new environment and may, as such, not be fully representative of the conditions that would prevail at a later stage, when users would have gotten used to the changes. While PTW rider behaviour would be unlikely to significantly differ (the only probable effect could be a slight increase in PTW speeds), it would be useful to repeat the observation study on the same site using videos collected at a later time period in order to confirm the validity of the findings reported.

Furthermore, a limitation of the behavioural observation study is the fact that, due to data availability and time and resource constraints, only one day of video footage per location could be analysed for the before and after case. While every effort has been made in order to ensure that the chosen days are as representative as possible, the eventuality of a bias in the results due to potential one-off events cannot be completely ruled out. It would be, hence, useful for future research to concentrate on analysing more days in order to confirm that the behavioural traits observed and the conclusions drawn are adequately reliable.

Moreover, the stated preference study on PTW rider perceptions is constrained by the fact that, despite its numerous advantages, the chosen binary logistic regression analysis has, like all fixed effects models, certain limitations. These are comprehensively appraised in (*37*), but the most important ones in the context of this study are potential limited external validity and unobserved heterogeneity. Indeed, the eventuality of the sample of respondents used in this study not being representative enough must be acknowledged (e.g. it is possible that respondents from outside the UK are under-represented in the sample), as should be the likelihood that additional variables that could not be measured may have effects on the willingness of PTW users to share space with other road users (e.g. it is possible that, despite the definition provided in the survey, different respondents would have developed a different understanding of shared space). Time and resource constraints have meant that these issues could not be investigated here, but future work could concentrate on exploring them further by performing additional surveys, including on-site ones, and by employing more advanced analysis methods, such as mixed or random effects logistic regression.

Finally, it would be useful to extend the scale of the observation study to other sites so as to be able to extract more generic conclusions and investigate how motorcyclist behaviour and perceptions vary with different combinations and extents of shared space features. In particular, it would be interesting to introduce a cultural dimension to the analysis and investigate how the behaviour and perceptions may change between different cities and countries. This will form a solid basis towards the overall goal of ensuring that the needs and particularities of all road users, including PTW riders, are fully addressed in new designs.

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Figure 1 Click here to access/download;Figure;Figure 1.docx

Source: Stilfehler, Wikimedia

FIGURE 1: Shared space examples: New Road, Brighton, UK (left); 16th Street Mall, Denver, CO, USA (right)

Figure 2 Click here to access/download;Figure;Figure 2.docx

(a)

(b)

(c)

(d)

Source: Royal Borough of Kensington and Chelsea

FIGURE 2: Exhibition Road before (left) and after redevelopment (right): (a) main body; (b) Thurloe Street; (c) one-way system unravelling (black arrows: previously permitted movements; blue arrows: newly permitted movements); (d) Cromwell Road junction.

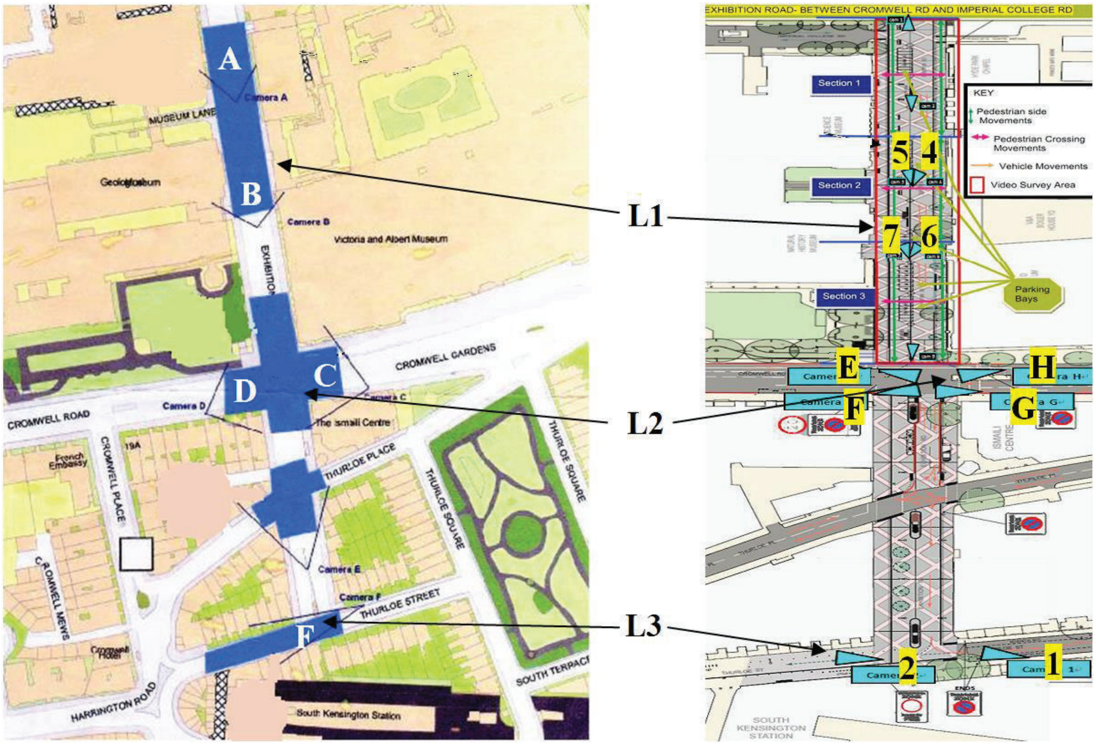

FIGURE 3: Camera locations at the Exhibition Road site in the before- (left) and after-monitoring (right)

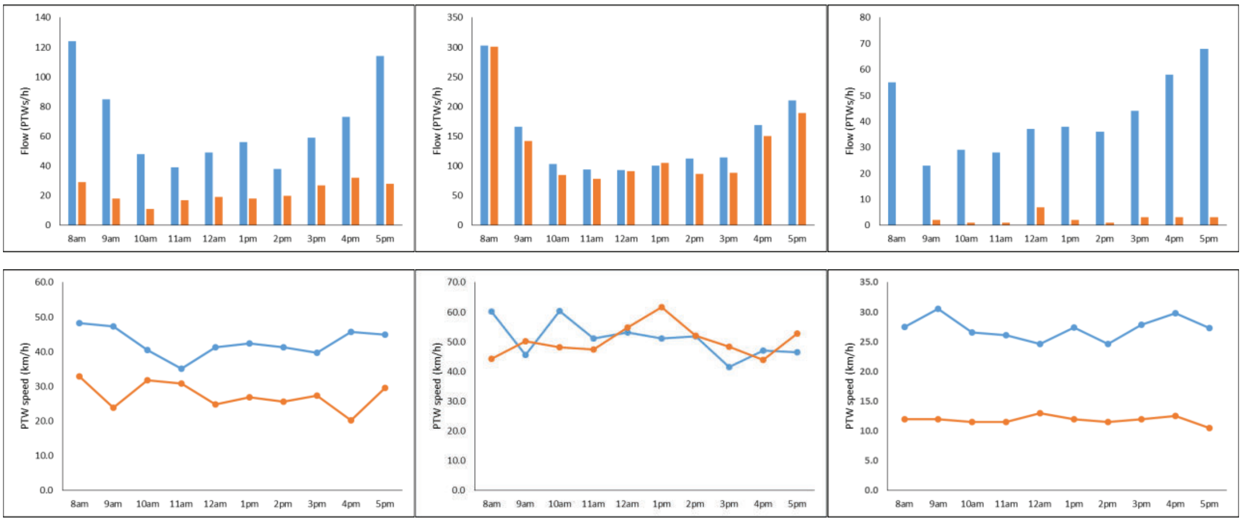

FIGURE 4: Hourly flow (top) and speed (bottom) of PTWs before (blue) and after (orange) the redevelopment for L1 Exhibition Road (left), L2 Cromwell Road (middle) and L3 Thurloe Street (right)

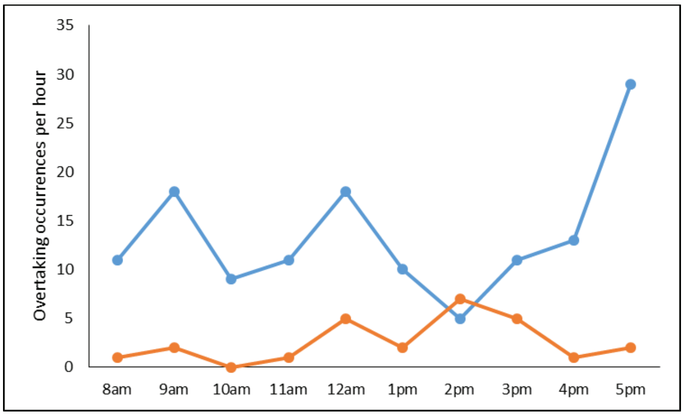

FIGURE 5: Overtaking events of PTWs before (blue) and after (orange) the redevelopment of the Exhibition Road main body (L1)

Figure 6 Click here to access/download;Figure;Figure 6.docx

Question 2.

Would you be willing to ride along the below street and share the space with vehicles and pedestrians?

There are **not many** pedestrians.

The size (street width) of the street space is **big**.

There are **several** obstacles (e.g. trees/plants, seating, fountains, etc.) present.

The street surface is **smooth** (i.e. there are few potholes, bumps etc.).

The street has a **low level of lighting** (for example there is dim lighting at night).

There are **many** vehicles around.

There are **several** motorcycles around.

- ○ Yes
- ○ No

FIGURE 6: An example scenario

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TABLE 1: Dates and times of PTW observation exercise

		Date(s)	Time
Before			
Location L1	Camera B	Tuesday 26 August 2008	8am-6pm
Location L2	Camera D	Tuesday 26 August 2008	8am-6pm
Location L3	Camera F	Wednesday 27 August 2008	8am-6pm
After			
Location L1	Camera 6	Wednesday 14 December 2011	8am-6pm
Location L2	Camera F	Monday 31 October 2011	8am-6pm
Location L3	Camera 1	Thursday 24 November 2011	8am-6pm

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TABLE 2: The flow and speed of PTWs before and after the redevelopment

Location	Camera	Average flow (PTWs/h)	Peak flow (PTWs/h)	Average speed (km/h)	Speed COV
Location L1 (before)	B	68.5	124	43.4	0.228
Location L2 (before)	D	146.4	303	51.1	0.198
Location L3 (before)	F	41.6	68	27.5	0.189
Location L1 (after)	6	21.9	32	27.6	0.312
Location L2 (after)	F	131.6	301	50.3	0.237
Location L3 (after)	1	2.3	7	11.9	0.210

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TABLE 3: Attributes and levels

Attribute	Description	Level
Pedestrians (PD)	The number of pedestrians in the street	Many / Not many
Space Size (SS)	The size (length and width) of the street space	Big / Small
Obstacles (OB)	Presence of obstacles (trees/plants, seating facilities, etc.)	Several / Few
Surface Condition (SC)	The condition of the street surface (due to potholes, bumps, ...)	Smooth / Rough
Lighting Level (LL)	The level of lighting provided (e.g. day- or night-time)	Good / Low
Vehicles (VT)	The number of vehicles in the street	Many / Not many
Motorcycles (MT)	Presence of other motorcycles in the street	Several / Few

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TABLE 4: The set of 8 scenarios used in the survey in binary format

Factor	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Label	**PD**	**SS**	**OB**	**SC**	**LL**	**VT**	**MT**
Definition	***1***	***2***	***3***	***1*2***	***1*3***	***2*3***	***1*2*3***
Scenario 1	-1	-1	-1	+1	+1	+1	-1
Scenario 2	+1	-1	-1	-1	-1	+1	+1
Scenario 3	-1	+1	-1	-1	+1	-1	+1
Scenario 4	+1	+1	-1	+1	-1	-1	-1
Scenario 5	-1	-1	+1	+1	-1	-1	+1
Scenario 6	+1	-1	+1	-1	+1	-1	-1
Scenario 7	-1	+1	+1	-1	-1	+1	-1
Scenario 8	+1	+1	+1	+1	+1	+1	+1

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TABLE 5: Response numbers to the eight scenarios

Scenario	Attribute							Responses	
	Pede-strians	Space size	Obstacles	Surface condition	Lighting level	Vehicles	Motor-cycles	Yes	No
1	Many	Small	Several	Smooth	Good	Not many	Several	9	28
2	Not many	Small	Several	Rough	Low	Not many	Few	12	25
3	Many	Big	Several	Rough	Good	Many	Few	12	25
4	Not many	Big	Several	Smooth	Low	Many	Several	30	9
5	Many	Small	Few	Smooth	Low	Many	Few	11	27
6	Not many	Small	Few	Rough	Good	Many	Several	22	16
7	Many	Big	Few	Rough	Low	Not many	Several	16	22
8	Not many	Big	Few	Smooth	Good	Not many	Few	36	2

 Click here to access/download;Table;Table 6.docx

TABLE 6: Results of binary logistic regression for PTW riders' willingness to share space

Attribute	Variable	Coefficient (β)	Standard error	Significance
Male	GEN_1	0.096	0.350	.784
30-49 years old	AGE_1	0.000	0.318	.999
Over 50 years old	AGE_2	-0.514	0.406	.206
Riding frequently	FRQ_1	0.463	0.312	.137
Big motorcycle	MTP_1	1.391	0.410	.001
Many pedestrians	PD_1	-1.798	0.309	.000
Big street space	SS_1	1.448	0.306	.000
Several obstacles	OB_1	-0.892	0.305	.003
Smooth surface condition	SC_1	0.935	0.305	.002
Good lighting level	LL_1	0.556	0.304	.068
Many vehicles	VT_1	-0.206	0.304	.498
Several motorcycles	MT_1	-0.117	0.304	.701
Constant		-1.184	0.564	.036

Number of observations = 302; chi^2 = 94.228; Sig. = .000; Pseudo-R^2 (Nagelkerke) = 0.357
Hosmer-Lemeshow goodness-of-fit test: chi^2 = 8.779; Sig. = .361