



Usage patterns and preference for car sharing: A case study of Dublin

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ARTICLE INFO

Keywords:

Car sharing
Urban mobility
New modes of transport

ABSTRACT

The popularity of mobility sharing services are growing rapidly around the world. Car, bike and scooter sharing services and movements towards the Mobility as a Service (MaaS) model have all shown the potential in these services to change how we think about mobility. The research presented in this paper examines the usage of a car sharing service in Dublin, Ireland. The research is divided into two parts, an analysis of booking data and a survey of Yuko's members. A 22-month sample size from January 2017 to October 2018 (660 days) of data contains 7,944 individual car bookings from 1,446 accounts containing 2,006 individual users. A survey was also conducted of over 400 Yuko users to determine how users perceived the service and how and if using this service changed their mobility patterns. A cluster analysis was conducted on this survey data that identified to specific groups, which were mainly defined by their car ownership status.

The research shows the more trips a user makes, the more likely they are to take quicker and shorter trips. Whereas those who rarely make a booking, make a longer journey when they do so. Some of the other findings were that users are generally young males, bookings tend to be much longer on the weekends and the majority of members do not currently own a car. It was found that members don't use car sharing as a means of commuting, but as a way to get around for a variety of reasons outside of their regular commute. The findings of the paper show that only a small number of users had sold their car since joining the service, mainly because they did not own one to begin with.

1. Introduction

Car sharing internationally is growing rapidly, Europe is the second largest global market with just over 20% of global membership of car sharing schemes (Shaheen and Cohen, 2020). Yuko (meaning "Let's Go" in Japanese) is a car sharing is a service, operated by Toyota in Dublin, where a person can use a vehicle on a pay-as-you-go basis. Research was carried out on the habits of members of Yuko, it aims to determine how car sharing schemes can benefit society and can this impact on the concept of car shedding. These types of services have operated on a large scale since 1987 when the first scheme began in Switzerland, although there had been some smaller-scale projects before this (Enoch and Taylor, 2006). Today there are many countries across the world where car sharing services have been set up, including here in Ireland where this project will focus on.

At the time this research was undertaken in 2018, Yuko had 2,006 individual registered users across 1,466 accounts (there can be multiple users on each account). Members can book a car in advance for a trip and then return the car to the same location that they departed from. Those over the age of 20 with a full driving license can sign up to the service

and after an initial €10 sign-up fee (Toyota, 2018).

The aim of the research is to determine if the use of car sharing leads to a reduction in private car ownership or purchasing a new car and to discover if there are any notable usage patterns amongst Yuko members. The objectives of the research are to answer the following questions:

- Are users of the scheme likely to give up their own cars
- What types of journeys are taken by car sharing members
- Does membership of a car sharing scheme result in a change in use of public transport and active modes

The paper adds to the body of research in this area and provides a case study of how the Yuko system is operating in Dublin. The paper provides evidence on how car sharing schemes are changing car ownership levels and are providing an alternative that complements public transport services.

2. Literature review

The growth of vehicle sharing services gained momentum in North

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<https://doi.org/10.1016/j.cstp.2020.12.007>

Received 23 July 2020; Received in revised form 2 November 2020; Accepted 28 December 2020

Available online 2 January 2021

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America in recent years and it is seen as the origin of this new type of mobility (Shaheen et al., 2012). In a seminal paper by Shaheen et al. (1998) demonstrated that carsharing provides the potential to reduce the costs of vehicle travel to the individual as well as the society. They concluded that car sharing organisations are more likely to be economically successful when they provide a dense network and variety of vehicles, serve a diverse mix of users, create joint-marketing partnerships, design a flexible yet simple rate system and provide for easy emergency access to taxis and long-term car rentals. While globally there is a move towards less single occupancy vehicle usage, the literature does indicate that car sharing using electric vehicles is one solution in low carbon future (Bergman et al., 2017; Mounce and Nelson, 2019). Rabbitt and Ghosh (2013) in a study conducted on a car sharing scheme in Dublin found that the city has a large potential to increase car sharing and identified if realised it could result in a large emission savings. Carroll et al. (2017) in a study also conducted in Dublin, found that potential users of a car-sharing scheme that improved convenience, priority parking and financial incentives would encourage people to use this mode.

2.1. Potential for car shedding

One of the benefits that's often cited that car sharing can bring is the concept of car shedding, that is people giving up a car for other modes of transport (Carroll et al., 2017). Carroll et al. (2017) shows that in a study, also in Dublin, individual commuters need sufficient incentives to interrupt commuting habits that may have been in place for considerable amount of time before joining something like a car sharing scheme. These incentives were shown to range from lower cost parking to faster travel times. However, the problem can be complex, Becker et al. (2018) examined changes in car ownership levels due to car sharing usage and found that the results indicated that a number of factors impacted on a reduction in car ownership rates and it wasn't exclusively car sharing. Nijland and van Meerkerk (2017) in a study of car sharing users in the Netherlands that reductions in car ownership did occur but this was mainly limited to second and third cars. Namazu and Dowlatabadi (2018) examined the intentions of car sharing users to a termination of the service in Vancouver. The findings showed that in the event of a termination of service, those that had given up a car were more likely to lease or purchase one again, this it is argued shows the how these services enable in car shedding. Kim et al. (2019) reports the findings of on the behaviour of car sharing users in Seoul and showed that shedding a car was more likely for those using the scheme for business and commuting trips compared to those using it for non-work trips.

A growing area of the literature examines how users of car sharing schemes that use electric vehicles can result in users being more likely to purchase electric vehicles in the future. While it this may not be as sustainable as car shedding it is a positive and sustainable side effect. Shaheen et al. (2020) examined the future car purchasing intentions of those that had used electric and plug-in electric vehicles in a car sharing scheme and they found that those that had used these vehicles were more likely to consider one of these vehicles in their next car purchase. Providing electric cars as the vehicle in a car sharing scheme has also been shown to increase the likelihood of users opting to choose car sharing (Carteni et al., 2016; Burghard and Dütschke, 2019). The current empirical evidence suggests internationally many schemes have resulted in a reduction of car ownership and a decrease in travel due to the introduction of car sharing schemes.

2.2. Changes in mode share

Efthymiou et al. (2013) found that members of car sharing schemes were more likely to be younger with higher education levels. They also found that those that were more likely to shift to car sharing were likely to move from public transport modes. Martin and Shaheen (2011) also found a statistically significant reduction in the use of bus and rail as a

result of using car sharing. Becker et al. (2017a,b) examined the relationship between public transport and car sharing and found in Switzerland that the two were complementary rather than rivals. The research found that public transport subscriptions and car sharing usage were linked and perhaps promoted a public transport-orientated lifestyle. Tyndall (2019) also argues this point and presents a case study of a public transport outage in Vancouver and demonstrates how car sharing stepped in to become a replacement mode of mobility. The research argues that the two modes are substitutes and that they form part of a larger integrated network. The results from cities with well-established and efficient public transport systems suggest that having such a system in place enables car shedding as users can use public transport and car sharing for the trips that are not convenient by public transport (Kim et al. 2019; Rotaris et al., 2019; Mugion et al., 2018).

The growing interest internationally in Mobility as a Service (MaaS) is resulting in a combining of car sharing, bike sharing and public transport to offer people sustainable mobility alternative. Research has shown that users of a car sharing scheme are more likely to public transport users and have public transport subscriptions (Münzel et al., 2019; Morsche et al., 2019). Therefore the bundling or packaging of these services is seen as a way of providing a sustainable and flexible mobility alternative (Esztergár-Kiss and Kerényi, 2020; Zhou et al., 2017). The current research suggests that car sharing and public transport coalesce in most cities and rather than compete with each other they provide sustainable transportation option.

This paper examines car sharing from two aspects, it looks at booking data and usage trends from a service based in Dublin and it also examines users' motivations from a survey of subscribers to this service. This enables this research to provide an analysis of the potential for car shedding behaviors and to determine what trips are being substituted when using a car sharing service. This is where the real benefits of a system like car sharing lie in that they can replace the car for nonflexible trips and enable users to be free of car ownership. Shaheen et al. (2019a, b) presents a comprehensive overview of the benefits of car sharing and the findings presented in our paper adds to this body providing more evidence of the potential of this mode.

3. Research methods

3.1. Booking data analysis

The first stage of this research examined the booking data from the 1st January 2017 to the 22nd October 2018. This 22-month sample size (660 days) of data contains 7,944 individual car bookings from 1,446 accounts containing 2,006 individual users. This works out as 12 bookings per day, however the bookings per day rate would have been increasing over time as Yuko added more vehicles and locations. Every time a user made a booking and rented a car, all data regarding the time, duration, distance travelled, pickup/drop-off location and cost of that particular booking was recorded. Table 1 details the descriptive statistics of the variables used in the regression analysis of the booking data.

For each booking that was made, the unique user ID for that Yuko member was listed. These were 32 characters long containing both numbers and letters. The number of individual users who had made a booking in the time period being analysed was 1,063, this is 53% of all of Yukos registered users.

For the analysis method selected it was deemed necessary to divide some of the variables into quartiles, this was due to the large spread of values in some of the variables examined. This was the case for the fourth quartiles in the variables presented in Table 2. Table 2 details three of the most important user variables collected during the study. The first variable relates to frequency of usage, these variable measures how often subscribers use the service. The next two variables measure the duration and distance traveled of the trips completed.

When a booking is made, the vehicle must be returned to the same street or space in which it was found. This location is recorded for each

Table 1
Descriptive Statistics – booking data.

		N	%
Distance Travelled	0.1–12 km	1,591	26.6
	12.1–27 km	1,425	23.8
	27.1–68 km	1,471	24.6
	68.1 + km	1,494	25.0
	Total	5,981	100.0
Start Time	Before or at 10:13:00	1,570	24.9
	Between 10:13:01 and 13:18:00	1,575	25.0
	Between 13:18:01 and 17:26:59	1,575	25.0
	At or after 17:27:00	1,577	25.0
	Total	6,297	100.0
Location	Northside Dublin	1,858	23.4
	West and Central Dublin City	1,582	19.9
	East Dublin City	1,995	25.1
	South Dublin	1,448	18.2
	Corporations	1,061	13.4
	Location	7,944	100.0
Duration	0.1–69 mins	1,581	25.2
	69.1–163 mins	1,558	24.8
	163.1–514 mins	1,571	25.0
	514.1 + mins	1,567	25.0
	Total	6,277	100.0
Vehicle Type	Small – medium car	6,363	80.6
	Sports utility vehicle	1,527	19.4
	Total	7,890	100.0

Table 2
Quartiles examined.

Frequency of usage	
Quartile 1	7 trips or less
Quartile 2	8 to 18 trips
Quartile 3	19 to 42 trips
Quartile 4	Over 42 trips
Duration of trip	
Quartile 1	0.1–69 min
Quartile 2	70–163 min
Quartile 3	164–514 min
Quartile 4	Over 515 min
Distance travelled	
Quartile 1	0.1–12 km
Quartile 2	12.1–27 km
Quartile 3	27.1–68 km
Quartile 4	68.1 + km

booking, so it was possible to analyse each location in terms of how often a booking was made there. The service is provided at a number or corporate locations and on a street level for four areas in the city. Locations 1–3 are all within the metro region of Dublin with good public transport connections, high concentrations of employment and are densely populated. Location 4 is in the South East suburbs of Dublin. These four areas and the corporate Yuko locations were branded Locations 1–5 as seen below and are circled on the map showing Yuko locations in Fig. 1 and a description of the areas is provided in Table 3.

After the booking data had been formatted and the majority of it split into quartiles a series of multinomial logistic regression models were estimated. This statistical analysis was selected as it provides the researcher with a powerful tool to compare the impacts of different variables. This approach had been used in other similar studies that examined usage patterns of shared mobility modes (Caulfield et al., 2017; Wang and Lindsey, 2019; Becker et al., 2017a, 2017b).

In this research two multinomial regression models were to be created as part of the booking analysis. The R^2 value, known as the coefficient of determination, is the proportion of the variance that is predictable from the independent variables. Each model would have a number of bookings left out from the total number of bookings due some bookings not containing information on each of the relevant variables. Each model contains subpopulations and these are noted in the results. The multinomial regression models take the form of:

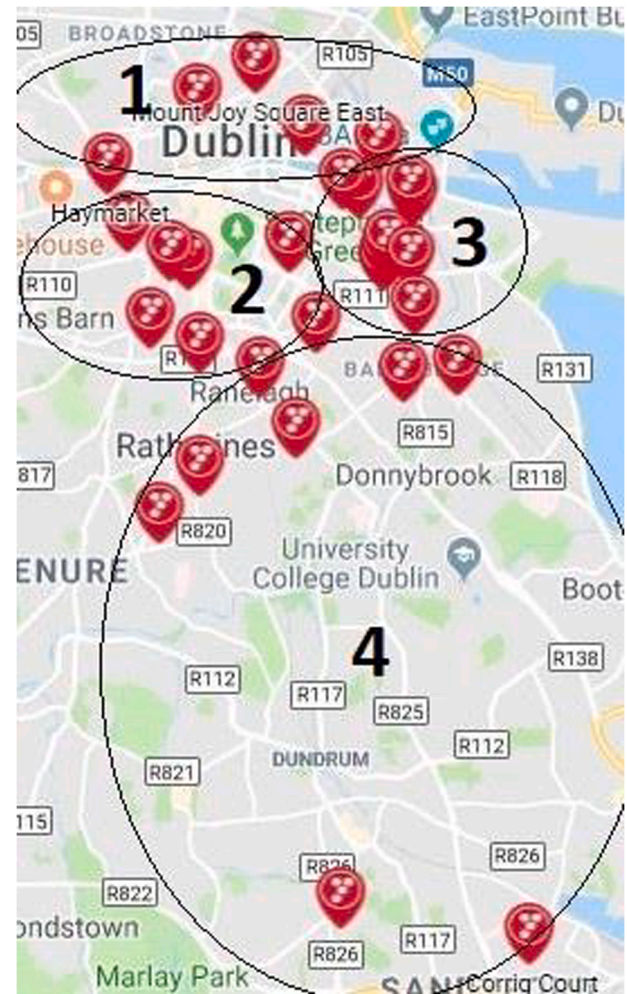


Fig. 1. Map of Yuko stations.

Table 3
Descriptions of the area.

Location	Description of the area
1 Northside Dublin (8 car locations)	Mainly commercial and retail zone, densely populated
2 West and Central Dublin City (9 car locations)	Mainly commercial and retail zone, densely populated
3 East Dublin City (9 car locations)	Mainly commercial and retail zone, densely populated
4 South Dublin City (8 car locations)	Mainly suburban
5 Corporate Locations (4 car locations)	Not shown in Fig. 1

$$\logit(p) = \log\left(\frac{p}{1-p}\right) = \alpha + \beta T + e \quad (1)$$

where: (Table 1 provides a description of these variables)

p = the probability that the event occurs, in this case it is that either the User Type (dependent variables)

α = intercept (constant),

βT = the set of trip characteristics (Booking Actual Duration or User Type; Distance Travelled, Start Time, Location and Vehicle Type),

e = random error term.

The dependent variable used in the regression analysis is user type.

The regression model test the impacts that the frequency of usage has upon duration of booking, time of day, distance travelled and vehicle.

3.2. Survey and analysis methods

In order to determine user opinions of the Yuko service a survey was conducted. The survey was sent to all 2,007 members of Yuko in November 2018, of which 401 responded, a response rate of 19.98%. The survey consisted of 25 questions which covered a variety of topics to ascertain how car sharing and public transport interact in Dublin and what level of car shedding has occurred.

The main analysis tool used on the survey data is a two-step cluster analysis. This analysis groups respondents by common themes in their responses to the survey. This method provides a succinct way to examine the survey data and provide insights into the data collected. Cluster analysis is a commonly used process that segments populations into homogenous subgroups, based upon common variables, allowing the researcher to gain insights into the trends in the data (Garson, 2012).

Table 4 details the demographics of the survey collected and compares it to the population in Dublin from the 2016 Census. The results show that the sample collected deviates substantially from that of the Census. The deviation is largest when comparing gender (with a higher proportion of males using the service) and in the age profile with the majority of car sharing users in the younger age groups. While this may be seen as a limitation of the research, the analysis presented in this section of the paper does not make any inferences to the general population, rather it just seeks to interrogate the sample collected.

4. Results

4.1. Booking data analysis results

4.1.1. Overview of usage

The first set of results in Table 5 lists each of the five locations that

Table 4
Survey Demographics.

		Survey Sample		Census 2016		Difference
		N	%	N	%	%
Gender	Male	324	81.0	486,392	46.8	34.2
	Female	76	19.0	552,822	53.2	−34.2
	Total	400	100	1,039,214	100.0	
Age	20–29	148	36.9	203,552	20.2	16.7
	30–39	170	42.4	243,970	24.2	18.2
	40–49	57	14.2	186,747	18.5	−4.3
	50–59	23	5.7	148,839	14.8	−9.1
	60+	3	0.7	225,550	22.4	−21.7
	Total	401	100.0	1,008,658	100.0	
Nationality	Irish	171	42.6	1,094,986	83.0	−40.4
	Non-Irish	230	57.4	224,116	17.0	40.4
	Total	401	100.0	1,319,102	100.0	
Profession	Employer and Manager	69	17.2	241,883	18.4	−1.2
	Higher professional	243	60.6	124,836	9.5	51.1
	Lower professional	43	10.7	171,934	13.1	−2.4
	Non-manual	4	1.0	261,082	19.8	−18.8
	Manual skilled	8	2.0	96,384	7.3	−5.3
	Semi-skilled	3	0.7	88,725	6.7	−6
	Unskilled	1	0.2	43,541	3.3	−3.1
	All others	3	0.7	215,824	16.4	−15.7
	gainfully occupied and unknown					
	Not currently working	27	6.7	71,103	5.4	1.3
	Total	401	100.0	1,315,312	100.0	

the Yuko locations (shown in Fig. 1). For the duration quartiles, the first quartile is the quickest trips and the fourth quartile contains the longest trips taken. Those who took the least amount of trips took the longest trips on average (765.64 mins), while those who took the most trips took the shortest trips on average (322.38 mins). This trend is seen clearly in the percentage breakdown for each quartile. Once more, the standard deviations in each case are quite large, indicating that the booking actual duration values are spread out over a wide range of values. When including all bookings made, the average booking actual duration was 522.57 mins, which suggests that the longest trips are so much longer than the shortest trips that the mean value would fall in the fourth quartile.

The location groups are listed in Table 6 and segmented by distance quartiles. The first quartile is the shortest trips and the fourth quartile is the longest trips. Northside locations again have the lowest mean value (64.05 km) and West and Central City locations have the highest mean value (96.24 km).

Table 7 shows that the less frequent the user is, the longer their trips are on average. The mean distance travelled for users taking 7 or less trips is 3.5 times larger than the mean distance travelled for those who took 42 or more trips. When accounting for all users, the mean value is 77.05 km which would put it in the fourth quartile. This is similar to the mean value for the booking actual duration, as the presence of many significantly long trips ensure that the mean value is relatively large.

Table 8 shows the difference between bookings on Weekdays vs Weekends. The weekend values include Friday as many users would take trips that last the whole weekend and begin on Friday. At the weekend, the mean distance travelled is almost twice as long as during the week, while the duration is over 50% longer. One could assume that the reason for these figures is that people will take longer, recreational trips at the weekend, that may even last a couple of days, while during the week most bookings last for less than an hour.

4.1.2. Regression analysis

This section includes the two booking data multinomial regression models that were estimated as part of this research. In the first model, in Table 9, the User Quartile as the dependent variable, while the Distance Travelled Quartile, the Start Time Quartile, the Location, the Duration Quartile and the Vehicle Type are the independent variables. This overall model has a Nagelkerke R^2 value of 0.14 which is low. However, the purpose of each trip is not known and neither is the identity or demographics of each user, meaning that the variables included in the model do predict the variance in journey times to a certain extent as each of them are deemed to be significant in the modelling results. The other three categories that are compared with this reference category (over 42 trips per month) are the users who took 7 or less trips (the least frequent), those who took between 7 and 18 trips and those who took between 18 and 42 trips. The more frequent users tend to take quicker and short trips when compared to less frequent users. It was also significant that the most frequent users were more likely to begin their trip in the early morning than other users.

4.2. Survey results

Table 10 presents the results of the initial cluster analysis conducted on the survey sample and shows the type of variable analysed and the relative predictor importance level. This predictor importance level indicates the relative importance of each of the variables in defining the cluster. Unsurprisingly come up car ownership and more choice for non-work trips were found to have the greatest importance in this analysis. The Silhouette value is a measure of how similar the data in the cluster is, these values range between −1 and +1, with a higher positive value indicating that the cluster formulation is appropriate.

The cluster analysis identified two main clusters from the survey data. Each cluster is defined by car ownership and the main characteristics of the clusters are detailed below.

Table 5
Duration for each User Quartile.

Quartile	Shortest Trips (%) 0.1–12 km	Short to Intermediate Trips (%) 12.1–27 km	Intermediate to Further Trips (%) 27.1–68 km	Furthest Trips (%)68.1 + km	Mean (Mins)	Standard Deviation (Mins)
1	13.40	22.10	24.80	39.70	765.64	1,120.446
2	21.20	24.80	28.40	25.50	603.16	1,259.375
3	29.10	28.50	23.30	19.10	409.00	903.000
4	36.50	23.80	23.70	16.00	322.38	762.534
All Users	25.05	24.80	25.05	25.08	522.57	1,040.728

Table 6
Distance Travelled for each Location.

Location	Shortest Trips (%) 0.1–12 km	Short to Intermediate Trips (%) 12.1–27 km	Intermediate to Further Trips (%) 27.1–68 km	Furthest Trips (%) 68.1 + km	Mean (km)	Standard Deviation (km)
1	28.50	26.40	24.70	20.40	64.05	150.141
2	17.40	24.60	26.00	32.00	96.24	168.129
3	22.90	23.90	26.60	26.70	81.88	149.550
4	26.60	19.50	28.00	25.90	82.09	158.183
5	47.90	24.80	11.10	16.20	46.67	90.523
All Locations	28.66	23.84	23.28	24.24	77.05	150.792

Table 7
Distance Travelled for each User Quartile.

User Quartile	Shortest Trips (%) 0.1–12 km	Short to Intermediate Trips (%) 12.1–27 km	Intermediate to Further Trips (%) 27.1–68 km	Furthest Trips (%) 68.1 + km	Mean (km)	Standard Deviation (km)
1	15.60	18.60	23.50	42.20	135.95	214.761
2	23.80	23.50	26.30	26.40	80.52	159.754
3	33.00	25.30	22.70	19.00	54.25	99.997
4	33.70	27.90	25.90	12.50	38.50	66.440
All Users	26.53	23.83	24.60	25.03	77.05	150.792

Table 8
Weekdays vs Weekends.

Time Period	Distance (km)		Duration (Mins)	
	Mean	Standard Deviation	Mean	Standard Deviation
Mon - Thu	53.11	116.130	403.750	986.800
Fri - Sun	97.12	171.633	621.940	1076.769

Cluster One – Car Owners: drive alone for non-work trips, Irish, have lived in their current residence for more than 10 years, mainly travel to work via public transport, the main motivation factor for using car sharing is not because it's cheaper than owning a car, live in the suburbs, mainly use car sharing for recreational trips and are most likely to be aged 20–29.

Cluster Two – Non-car Owners: use public transport for non-work trips, non-Irish, have lived in their current residence for 1–2 years, mainly walk to work, the main motivation factor for using car sharing is because it's cheaper than owning a car, live in the city centre, mainly use car sharing for recreational trips and are most likely to be aged 20–29.

The clusters are used in Table 11 to further interrogate some of the key questions asked in the survey. The analysis examines how since joining the car sharing scheme if individuals' preferences around mobility have changed. Two questions examine car ownership since joining the scheme and the results showed that those in the second cluster the non-car owners were more likely to have sold their only car, however it should be noted that this percentage was quite low at 7.8%. The results also showed that when asked if they had sold their second car, almost 15% of those in cluster one had said yes to this question. The results in relation to the usage of public transport, cycling, walking and taxis so very little deviation between the two clusters examined. One of the most striking results from Table 10 is that over 64% of the sample indicated that they use less public transport since joining the car sharing

scheme. A similar result was found for taxi usage with over 52% from both clusters indicating they used less taxis. These results would seem to suggest, that users reverted back to car usage over perhaps more sustainable modes of transport.

The results in Table 11 seek to examine the motivations for using a car sharing scheme. The first two questions are in relation to retail activities and demonstrate that those in cluster one rarely used the scheme where these activities will stop the results from cluster two showed that a substantial amount of users of the service purchased bulky items or day to day grocery shopping while using the car sharing scheme. The findings for the 'no public transport alternative' question found a little deviation between the two cluster groups and the results show that less than 24% said this was the reason that they use this service. When asking respondents was it the environmental credentials of using a car sharing service the main reason for them signing up, less than 20% of users said that this was their main motivation. The final question in the Table 11 asked was it trips outside of Dublin city centre that was behind their usage of the scheme. The results here show a clear difference between the two clusters with those in the second cluster, perhaps unsurprisingly, more likely to have stated this was the reason they signed up to the service.

The results for cluster two are interesting in that it would seem that these users are availing of the benefits of car ownership without the large sunk cost of ownership. This statement can be supported when looking at the main motivations for using the service linked to purchasing goods and bulky items and for travelling long distances. Further evidence for this can be seen in that there is very little deviation between the usage of public transport and active modes between the two clusters.

5. Policy discussion

The findings presented in this paper provide insights on how car

Table 9

Logistic Regression Model Results when the User Quartile is the dependent variable for all of the bookings.

	Intercept	User Quartile 1 ^a	User Quartile 2 ^a	User Quartile 3 ^a
		0.764**	0.833**	0.709**
Distance	0.1–12 km	–1.199**	–0.875**	–0.614**
Travelled	12.1–27 km	–1.295**	–0.937**	–0.761**
	27.1–68 km	–1.074**	–0.717**	–0.657**
	68.1 + km	0 ^b	0 ^b	0 ^b
Start Time	Before or at 10:13:00	–0.605**	–0.578**	–0.511**
	Between 10:13:01 and 13:18:00	0.004	–0.043	0.035
	Between 13:18:01 and 17:26:59	–0.190	0.021	–0.057
	At or after 17:27:00	0 ^b	0 ^b	0 ^b
Location	Northside Dublin	0.977**	–0.408	–0.237
	West and Central Dublin City	1.720**	0.356	0.585*
	East Dublin City	1.773**	0.736**	0.389
	South Dublin	1.126**	–0.320	–0.455
	Corporations	0 ^b	0 ^b	0 ^b
Duration	0.1–69 mins	–1.163**	–0.382*	0.173
	69.1–163 mins	–0.246	0.077	0.427**
	163.1–514 mins	–0.468**	–0.051	0.043
	514.1 + mins	0 ^b	0 ^b	0 ^b
Vehicle Type	Small – medium car	–0.557**	0.025	–0.191
	Sports utility vehicle	0 ^b	0 ^b	0 ^b
N				5969
–2Log-likelihood at convergence				3739.173
Nagelkerke R ²				0.148
Chi-squared statistic				892.16
Degrees of freedom				42

^a The reference category is: 30 users from 42 trips to 129.

^b This parameter is set to zero because it is redundant.

* Significant at a 95% level.

** Significant at a 99% level.

Table 10

Input variables – cluster analysis.

Variable	Scale	Relative predictor importance
Car ownership	Binary	1.00
Mode choice non-work trips	7 categories	0.65
Nationality	Binary	0.39
Duration living at current location	6 categories	0.32
Mode choice commuting trips	7 categories	0.32
Car sharing: cheaper than owning a car	Binary	0.27
Residential location	8 categories	0.24
Reason for use: recreational	Binary	0.19
Age	5 categories	0.13
Average Silhouette	0.45	

sharing can work in a medium sized city like Dublin and indeed mirrors the results found in other studies. The system examined in this research, at the time of the study, at a low number of vehicles in the fleet but the results demonstrate the potential of such scheme. Dublin City, like many others internationally, has several goals on reducing congestion, emissions and improving air quality. Car sharing can play a vital role in these objectives. Not all trips can be substituted with public transport or walking and cycling so in that case car sharing can play an important

Table 11

Clusters impacts on mobility.

		Cluster One: Car owners		Cluster Two: Non-car owners	
		N	%	N	%
Have you sold your only car since joining the scheme?	Yes	2	1.7	20	7.8
	No	114	98.3	238	92.2
Have you sold your second car since joining the scheme?	Yes	17	14.7	13	5.0
	No	99	85.3	245	95.0
Have you used less public transport?	Yes	38	32.8	92	35.7
	No	78	67.2	166	64.3
Have you cycled less?	Yes	23	19.8	42	16.3
	No	93	80.2	216	83.7
Have you walked less?	Yes	22	19.0	41	15.9
	No	94	81.0	217	84.1
Have you used fewer taxis?	Yes	67	57.8	135	52.3
	No	49	42.2	123	47.7
Use for grocery shopping	Yes	4	3.4	79	30.6
	No	112	96.6	179	69.4
Buying bulky items	Yes	8	6.9	104	40.3
	No	108	93.1	154	59.7
No public transport alternative	Yes	26	22.4	61	23.6
	No	90	77.6	197	76.4
Better for the environment	Yes	19	16.4	50	19.4
	No	97	83.6	208	80.6
For trips outside Dublin	Yes	13	11.2	124	48.1
	No	103	88.8	134	51.9

role, as shown. Car sharing can also support policies that suppress car ownership by providing a flexible alternative and consequently could result in a reduction in emissions. A scaling up of the current system in Dublin could see the benefits reported from this analysis intensify and over time and as car sharing is seen as a viable alternative to car ownership it would assist in goals reduced car ownership. The growth of MaaS, electrification and automation of our car fleets in the future may have the potential to transform how policymakers view car sharing and it will interact with traditional modes (Shaheen et al., 2019a, 2019b).

6. Conclusions

The research presented in this paper demonstrates how car sharing works in a medium sized city like Dublin. Carsharing has long been considered a method that would enable car shedding to occur by providing users would have flexible alternative that could be cost effective and efficient. The findings of the paper showed that a small percentage of users had sold our only car since joining the service and a slightly larger percentage said that they had sold a second car. While these percentages are quite low, they do demonstrate how car sharing maybe one of the solutions to reducing carbon emissions. Another factor that should be considered when looking at these results is that just over 30% of respondents to our survey indicated that they owned a car to begin with.

The results from the cluster analysis demonstrate that there are two very different types of users of the system. The main characteristic that defines the clusters is car ownership and the location in the city in which they live. Both clusters indicate the main motivation for using this scheme is the lower cost compared to car ownership, and we're most likely to use it for recreational trips. One difference between both clusters is that, the car owning cluster users were more likely to drive to work whereas the other cluster were more likely to use public transport. The results also showed that users from both clusters hadn't substantially reduced active mode and public transport usage.

The results from examining the booking data demonstrated that users were more likely to use the service for longer trips and this suggests that the service was replacing car rental or public transport use four weekends away. Longer distance trips and trips for purchasing groceries and larger items are often cited some of the main reasons for

car ownership. when focusing on the users in cluster 2 it is interesting to see that they are more likely to use the service for these trips and perhaps the service is suppressing the likelihood of car ownership within this group.

While the results from the survey do demonstrate that users are exhibiting more sustainable mobility characteristics, the results also show that few of the users are subscribe to the service as they feel it is better the environment. This area requires further research, as the service clearly demonstrates it can act as an enabler for car shedding and more sustainable mobility behaviours.

CRedit authorship contribution statement

Brian Caulfield: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing - original draft, Writing - review & editing. **James Kehoe:** Conceptualization, Formal analysis, Investigation, Methodology, Resources, Software, Validation, Writing - original draft, Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

The authors would like to thank Toyota Ireland for providing the data used in this study.

References

- Becker, H., Loder, A., Schmid, B., Axhausen, K.W., 2017a. Modelling Car-sharing membership as a mobility tool: A multivariate probit approach with latent variables. *Travel Behaviour Soc.* 8, 26–36.
- Becker, H., Ciari, F., Axhausen, K.W., 2018. Measuring the car ownership impact of free-floating car-sharing – A case study in Basel, Switzerland. *Transp. Res. Part D* 65, 51–62.
- Becker, H., Ciari, F., Axhausen, W., 2017b. Modelling free-floating car-sharing use in Switzerland: A spatial regression and conditional logit approach. *Transp. Res. Part C: Emerging Technol.* 81, 286–299.
- Bergman, N., Schwanen, T., Sovacool, B.K., 2017. Imagined people, behaviour and future mobility: Insights from visions of electric vehicles and car clubs in the United Kingdom. *Transp. Policy* 59, 165–173.
- Carroll, P., Caulfield, B., Ahern, A., 2017. Examining the potential for car-shedding in the Greater Dublin Area. *Transp. Res. Part A: Policy Practice* 106, 440–452.
- Carteni, A., Cascetta, E., de Luca, S., 2016. A random utility model for park & carsharing services and the pure preference for electric vehicles. *Transp. Policy* 48, 49–59.
- Burghard, U., Dütschke, E., 2019. Who wants shared mobility? Lessons from early adopters and mainstream drivers on electric carsharing in Germany. *Transp. Res. Part D: Transp. Environ.* 71, 96–109.
- Esztergár-Kiss, D., Kerényi, T., 2020. Creation of mobility packages based on the MaaS concept. *Travel Behaviour Society* 21, 307–317.
- Efthymiou, D., Antoniou, C., Waddell, P., 2013. Factors affecting the adoption of vehicle sharing systems by young drivers. *Transp. Policy* 29, 64–73.
- Enoch, M.P., Taylor, J.o., 2006. A worldwide review of support mechanisms for car clubs. *Transp. Policy* 13 (5), 434–443.
- Garson, G.D., 2012. Cluster analysis. Statistical Associates Publishers, Asheboro, NC.
- Mugion, R.G., Toni, M., Raharjo, H., Di Pietro, L., Sebathu, S.P., 2018. Does the service quality of urban public transport enhance sustainable mobility? *J. Cleaner Prod.* 174, 1566–1587.
- Martin, E., Shaheen, S., 2011. The Impact of Carsharing on Public Transit and Non-Motorized Travel: An Exploration of North American Carsharing Survey Data. *Energies* 4, 2094–2114. <https://doi.org/10.3390/en4112094>.
- Mounce, R., Nelson, J.D., 2019. On the potential for one-way electric vehicle car-sharing in future mobility systems. *Transp. Res. Part A: Policy Practice* 120, 17–30.
- Morsche, W.t., La Paix Puella, L., Geurs, K.T., 2019. Potential uptake of adaptive transport services: An exploration of service attributes and attitudes. *Transp. Policy* 84, 1–11.
- Münzel, K., Piscicelli, L., Boon, W., Frenken, K., 2019. Different business models – different users? Uncovering the motives and characteristics of business-to-consumer and peer-to-peer carsharing adopters in The Netherlands. *Transp. Res. Part D: Transp. Environ.* 73, 276–306.
- Namazu, M., Dowlatabadi, H., 2018. Vehicle ownership reduction: A comparison of one-way and two-way carsharing systems. *Transp. Policy* 64, 38–50.
- Nijland, H., van Meerkkerk, J., 2017. Mobility and environmental impacts of car sharing in the Netherlands. *Environ. Innovation Societal Transitions* 23, 84–91.
- Rabbitt, N., Ghosh, B., 2013. A study of feasibility and potential benefits of organised car sharing in Ireland. *Transp. Res. Part D: Transp. Environ.* 25, 49–58.
- Rotaris, L., Danielis, R., Maltese, I., 2019. Carsharing use by college students: The case of Milan and Rome. *Transp. Res. Part A: Policy Practice* 120, 239–251.
- Shaheen, S., Cohen, A., 2020. Innovative Mobility: Carsharing Outlook; Carsharing Market Overview, Analysis and Trends. <https://escholarship.org/uc/item/61q03282>.
- Shaheen, S., Cohen, A., Randolph, M., Farrar, E., Davis, R., Nichols, A., 2019. Shared Mobility Policy Playbook. Retrieved from <https://escholarship.org/uc/item/9678b4xs>.
- Shaheen, S., Cohen, A., Farrar, E., 2019b. Carsharing's Impact and Future Advances in Transport Policy and Planning 4, 87–120.
- Shaheen, S., Martin, E., Totte, H., 2020. Zero-emission vehicle expostue within the U.S. carsharing fleets and impacts on sentiment toward electric drive vehicles. *Transp. Policy* 85 (2020), 23–32.
- Shaheen, S., Sperling, D., Wagner, C., 1998. Carsharing in Europe and North America. Past, Present, Future.
- Shaheen, S.A., Mallery, M.A., Kingsley, K.J., 2012. Personal vehicle sharing services in North America. *Res. Transp. Business Management* 3, 71–81.
- Tyndall, J., 2019. Free-floating carsharing and extemporaneous public transport substitution. *Res. Transp. Economics* 74, 21–27.
- Toyota, 2018. "Yuko Car Club Launch," Toyota, 2016. [Online]. Available: <https://www.toyota.ie/world-of-toyota/articles-news-events/2016/yuko-car-club-launch.json>. [Accessed 11/09/2018].
- Wang, J., Lindsey, G., 2019. Neighbourhood socio-demographic characteristics and bike share member patterns of use. *J. Transp. Geogr.* 79, 102475.
- Zhou, F., Zheng, Z., Whitehead, J., Perrons, R., Washington, S., 2017. Projected prevalence of car-sharing in four Asian-Pacific countries in 2030: What do the experts think. *Transp. Res. Part C: Emerging Technol.* 84, 158–177.