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Examining Crash Factors in Free-Floating Carsharing

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Abstract

In this study, 2.2 million carsharing trips from a leading operator in Madrid were analysed to identify crash factors, focusing on driver age, gender, trip timing and prior platform usage. Using a logit model, the findings indicate higher crash probabilities among drivers aged 25 years and under, drivers with fewer than six prior trips on the platform, and trips between midnight and 7 am. Younger drivers and nighttime trips also show a stronger association with at-fault crashes compared to older driver and daytime trips. The quantitative analysis was complemented by eight interviews with company management (n=4) and service users (n=4). Their insights suggested that risky behaviour, inexperience and lack of ownership may contribute to these patterns. This research highlights the need for targeted carsharing regulations and operator strategies to mitigate risks, particularly for younger drivers.

Key findings

- Crashes in carsharing are more likely to occur when the driver is young and the trip takes place at night.
- At-fault crashes are also more frequent among young drivers and during nighttime trips.
- A low number of prior uses of the service is associated with a higher likelihood of crashes.

Introduction

Driving safety remains an ongoing concern. In 2021, in Europe alone there was an estimated 19,800 fatalities due to road crashes, with 40 percent occurring in urban areas (European Commission, 2022). With the increase of novel urban mobility paradigms, particularly carsharing, there has been considerable scholarly attention due to their potential implications for driving safety (Lorig et al., 2023). Carsharing, defined by Mounce and Nelson (2019) as “a model where customers rent cars for short durations from operators who maintain a fleet” (p. 26), has experienced a global upsurge (Li & Kamargianni, 2020). A notable innovation within this domain is the free-floating carsharing model, which permits users to leverage mobile technology to reserve, operate and return vehicles flexibly within a designated urban zone (Sprei et al., 2019).

Research focusing on crashes involving carsharing services remains notably limited, likely due to challenges in data access and consistent recording of the involvement of a carshare vehicle. Presently, only a handful of studies have scrutinised the intersection between carsharing and road safety, each with distinct research aims. Dixit and Rashidi (2014) analysed self-reported data from users of GoGet, a carsharing service in Sydney, Australia. Their findings indicated a higher likelihood of crash involvement among drivers with a shorter driving licence tenure, higher frequency of car usage, lack of personal car ownership, a history of past incidents and a preference for lower insurance deductibles. Notably, this study also revealed a greater propensity for at-fault crashes among carsharing users who rarely drove or did not own cars, suggesting limited driving experience as a significant factor in carsharing-related crashes. In a separate study, Shaheen et al. (2016) analysed company data from six carsharing operators to evaluate crash risks and insurance claims in the United States of America (US). This analysis, which calculated risk per mile and per insured vehicle year, differentiated by age and gender, revealed an elevated crash risk for drivers above 65 years when compared to other age groups and the national

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average. Additionally, the study found that teenagers and young drivers aged 18 to 25 years exhibited a marginally higher risk than adult drivers. Furthermore, the research indicated a generally lower crash risk for female drivers across nearly all age categories.

These studies underscore the significance of human factors in car crashes (Lord & Mannering, 2010; Mannering & Bhat, 2014) and highlight the relevance of variables uniquely associated with carsharing services, such as vehicle ownership and insurance deductibles. Among the well-studied human factors, age and gender are particularly important, with consensus in the literature that these factors significantly influence the likelihood of crashes. Concerning age, a substantial body of evidence indicates that younger drivers are at a heightened risk of collisions compared to older drivers (McCartt et al., 2009). This disparity is attributed to factors such as inadequate driving skills or tendencies towards aggressive driving (Jonah, 1986; Rolison et al., 2018), a diminished perception of danger, and an increased propensity for risk-taking behaviours (Factor et al., 2008). For younger drivers, this risk is further exacerbated during nocturnal journeys (Keall et al., 2005). In terms of gender, men have been consistently found more likely to be involved in motor-vehicle incidents than women (Evans, 1991; Massie et al., 1997; Shinar et al., 2001. The temporal context of driving also plays a crucial role, with studies indicating that nighttime driving significantly elevates crash risk (Keall et al., 2005). Factors such as alcohol consumption (Macinko et al., 2015) and driver fatigue (Horne & Reyner, 1999) are especially pertinent in this regard, often impacting younger drivers more severely (Shope & Bingham, 2008).

The carsharing model introduces a unique dynamic by separating vehicle use from ownership. This arrangement allows users to enjoy the benefits of private vehicle usage without the associated costs and responsibilities (Costain et al., 2012). However, the effects of non-ownership on driving behaviour and crash proneness remain underexplored. Existing research suggests that non-ownership influences how vehicles are treated (Bardhi & Eckhardt, 2012), potentially increasing risky driving behaviours. For instance, Tay and Choi (2016) observed that collisions involving taxi vehicles operated by non-owners, compared to those owned by drivers, could partly be explained by moral hazard and adverse selection. Moral hazard implies that drivers are incentivised to act in self-serving ways, such as driving fast, at the owner's expense if crash occurs; as an example of adverse selection, some individuals prefer operating a taxi without owning it to avoid bearing the full cost of their risky driving behaviour. In a subsequent study, the same authors (Tay & Choi, 2017) found that crashes involving rental cars were more often associated with risky behaviours, including poor driving, inattention and aggressive driving compared to non-rental cars. Furthermore, the lack of personal association with the vehicle has been linked to an increased likelihood of crash involvement, a phenomenon possibly attributable to unfamiliarity with the vehicle's specific features and handling characteristics (Tefft et al., 2019).

This article endeavours to expand the existing empirical evidence in the realm of carsharing by probing into a variable distinctly pertinent to shared mobility services: the frequency of prior usage by the driver on the platform. Additionally, this study examined the impact of well-established variables such as age and gender, and temporal factors, specifically the time of day. The investigation is further nuanced by examining the incidence of crashes and the allocation of fault in these incidents. Drawing upon the evidence outlined previously, we postulate that journeys undertaken by younger male drivers have a higher propensity for collisions and secondly, an increased probability of crashes during nighttime. Moreover, the likelihood of nighttime collisions was anticipated to be particularly elevated among younger drivers, a hypothesis stemming from their documented inclination towards riskier behaviours. These variables are examined using a two-year dataset of users provided by a carsharing operator in Madrid, Spain. By choosing this geographical context, this study also extends the contexts where carsharing crashes have been studied (Australia and US).

Understanding the contributing factors in carshare vehicle crashes is relevant for policymakers and urban planners, given the growing adoption of this mobility model in cities. Insights from this study have the potential to inform targeted strategies and policies aimed at bolstering driving safety within the carsharing paradigm.

Method

Data Source

This investigation leveraged a comprehensive dataset provided by Carsharing Mobility Services SL ("CSMS" or "Zity"), a prominent player in the free-floating carsharing sector. Established in October 2017, Zity is a Spanish free-floating carsharing provider, operating in Madrid with a fleet of electric vehicles. During the time in which data were collected, the company had over 600 motor vehicles in operation, all of them were the fully electric powered, Renault ZOEs. The dataset was anonymised by Zity in adherence with both internal and European Union data protection standards. The dataset detailed all trips taken via the platform in the two year period from 1 January 2018 to 31 December 2019. This dataset included an array of variables, such as the Time of Trip, Day of Week, Trip length, key driver demographics (e.g., Gender, Age) and pertinent details regarding vehicular crashes and driver culpability.

The quantitative analysis was complemented by interviews with Zity managers, including a member of the top management team (n=4) and Zity customers (n=4), forming part of a broader investigation into customer misbehaviour in shared mobility services including reckless driving. This mixed-method approach aligns with the work of Vergel-Tovar et al. (2020), who utilised interviews to interpret the results of their analytical model examining the relationship between road safety outcomes and the built environment. A detailed list of informants and interview questions are below.

Table 1. List of Interview participants

Participant	Age (years)	Gender	Description
Top management member	45	Male	Responsible for launching the business and managing global operations
Operations manager	40	Female	Responsible for managing the operations in Madrid
Customer Experience manager	44	Male	In charge of managing all interactions with customers, both inbound and outbound
Fleet Manager	30	Female	Managing the maintenance and repair of the fleet as well as the relationship with the insurance provider.
Customer 1	38	Male	Zity user - Frequent (at least once a week)
Customer 2	35	Female	Zity user - Frequent (at least once a week)
Customer 3	39	Male	Zity user - Occasional (once a month)
Customer 4	23	Male	Zity user - Occasional (once every three months)

Table 2. Interview questions

Participant type	Questions
Zity management	• Is there anything from the results of the quantitative analysis that strike you? • Can you provide specific examples of driving misbehaviour of Zity cars? • Have you detected any pattern in crashes? • Why do you think younger drivers show a higher likelihood of experiencing a crash? • Do you see differences in misuse of cars between use at night and the rest of the day? • Do you think that users get a sense of belonging with Zity, the car or the brand, as they use it more often? • Are there any differences between male and female drivers in the way they drive or use these vehicles?
Zity users	• Do you have a car? Do you think that having a car influences how you drive a Zity car? • How often do you drive a Zity car? • How would you define your style of driving when you drive a Zity car? Is it different that when you drive your own car? • How was your first experience driving a Zity car?

Variables

The study explained two binary dependent variables. The first dependent variable was crash, defined as an incident that required Zity to repair the vehicle at an external workshop. Minor blemishes or negligible incidents are neither detected nor recorded in this framework. The second dependent variable was driver culpability, defined as driver self-report (i.e., driver acknowledged responsibility through a 'friendly report'), a formal post-collision declaration signed by the drivers and subsequently forwarded to insurance firms or the driver concedes culpability when presented with evidence by the company.

The analytical model incorporated a set of independent covariates supplied by the company, namely driver Gender and Age, Previous trips, Day of Week and Time of trip and Trip length. Gender information was binary (female; male). Age (years) was calculated using trip date and the driver's date of birth. The age range of Zity users spans from 18 years to 90 years. To discern the variances between younger drivers and other user demographics more effectively, the Age variable was transformed into a categorical variable with two groups: 25 years and below and 26 years and above. This dichotomy was established based on data analysis, which indicated a heightened crash frequency among drivers aged 18 to 25 years compared to drivers above 25 years and is corroborated in the literature (McCartt et al., 2009; Shaheen et al., 2016; Zeyin et al., 2022). Previous trips via Zity variable was the cumulative number of trips a driver had undertaken with a Zity vehicle. Given the wide range of trip frequency, this variable was categorised into quartiles (Caulfield & Kehoe, 2021) to represent a distinct usage level of Zity services (0-5 trips; 6-16 trips; 17-44 trips; 45+ trips). Additionally, the model included Day of Week and Time of trip. Time of trip variable was segmented into five categories to reflect varying traffic conditions in Madrid (Early Morning: 7:00-10:59am; Morning: 11:00am-2:59pm; Afternoon: 3:00-8:59pm; Evening: 9:00-11:59 pm; Night: 12:00-6:59am). Lastly, Trip length measured the distance travelled per trip in kilometres and was incorporated to account for risk exposure. Given its highly skewed distribution, it was logarithmically transformed and modeled in a quadratic form to accurately represent the observed U-shaped pattern in the data analysis. Daily rainfall, used as a proxy for weather conditions, and the number of passing vehicles per hour on the M30 (Madrid's inner ring road), serving as a proxy for traffic intensity in the city, were also incorporated into the models.

Other factors that could influence crash rates, such as the type of motor vehicle or traffic regulations, did not change during the analysis period and are considered constant in the model. To ensure the robustness of the model against multicollinearity, the Variance Inflation Factor (VIF) was employed as a diagnostic tool. The VIF values for all variables were found to be lower than 2, a threshold generally accepted as indicative of minimal multicollinearity.

Analytical model

In this study, the primary unit of analysis was the individual trip. The two dependent variables are binary (crash and driver culpability). Given the dichotomous nature of the variables a discrete outcome model, a binomial logit regression, was employed. The primary objective of the study is to discern the impact of specific variables on the likelihood of a crash and the determination of driver culpability within the context of carsharing. All analyses were conducted using the statistical software Stata.

Results

The main descriptive statistics for the variables incorporated in the models are shown in Table 3. A comparative statistical analysis between trips culminating in crashes and those that did not was conducted. For binary variables, a Chi-Squared test was utilised to identify statistical differences between the two groups. For the continuous variable, trip length, a Mann-Whitney-Wilcoxon test was employed. Over the study period, a total of 2,177,496 trips were recorded, of which only 691 (0.03% of all trips) resulted in a crash. The dataset encompassed 135,572 unique users, with no instances of a user being involved in more than one crash.

The outcomes of the logit models are detailed in Table 4. In the model where the occurrance of a crash was the dependent variable, both Age and Gender were significant predictors. The positive coefficients for these variables indicate a heightened likelihood of crashes for trips involving young drivers (25 years and below: 0.968, $p<0.01$) and female drivers (0.201), albeit at $p>.05$. The first quartile of the Previous trips (0-5 trips: 0.336, $p<0.01$) also shows a significant positive correlation, suggesting an increased crash probability for drivers with five or fewer prior trips via the platform. Trips at night had a higher crash likelihood (0.351, $p<0.01$). However, the Day of Week was not statistically significant. Trip length was significant at $p<0.01$, indicating a U-shaped relationship between the distance driven and crash probability. In the model that analysed driver culpability, only Age (young drivers aged 25 years and under: 1.314, $p<.01$) and Night (1.274, $p<0.01$) were statistically significant, both exhibiting larger positive coefficients than in the first model.

To explore potential interactions between these variables, two additional models incorporating the interaction between Age and Time of trip (Night) were computed (Table 5). The coefficients for the interaction between Time of trip (night) and Age (25 years and under) in both the Crash/No-crash model (1.784, $p<.01$) and the driver At-fault/Not-at-fault models models (2.686, $p<.01$) were higher than the separate effects of these variables, with the Previous trips variable retaining its statistical significance only in the Crash/No-crash model (0.306, $p<.01$).

The interviews provided qualitative insights that enriched quantitative results. Zity managers expressed little surprise at the findings, unanimously highlighting a correlation between collision rates and the age of drivers, noting that younger users often engaged in inappropriate vehicle use, such as illegal racing or aggressive driving manoeuvres.

> *"In many crashes the driver is very young. When we talk to them, it is clear that they have very limited driving experience...The worst accidents, from an economic point of view, are caused by young drivers. I remember a 19 year old who had an accident and the car was completely destroyed. It was not worth it to repair it."*
> Zity operations manager

> *"For me it is clear that age and night are correlated with more crashes because cars are misused: speeding, alcohol, not observation of traffic lights, etc."*
> Zity customer experience manager

> *"Speeding, performing dangerous manoeuvres, and engaging in illegal racing is more common in a certain age range, the younger, and at particular times of the day, at night. This is when crashes are more common"*
> Zity fleet manager

Managers also confirmed that nighttime was strongly associated with higher incident rates, often linked to alcohol use.

> *"Users do not care what happens to the car because it is not theirs. They do things that they would not do with their own car such as drinking alcohol and driving...We have had to pick up cars that were involved in an accident in the middle of the M30 on a Friday night where the driver had disappeared. They prefer that we fine them than doing the alcohol test with the police"*
> Zity top management member

Additionally, managers noted the increased crash likelihood among drivers in the first quartile of the Previous trips variable, suggesting that unfamiliarity with automatic electric vehicles during Zity's early years may have contributed to these incidents.

> *"In the early years, customers were not used to electric vehicles. I am sure that contributed to crashes. We had instances of trips where crash occurred only a few hundred metres after started"*
> Zity operations manager

The top management team member added that customers generally treated Zity cars with less care than their personal vehicles, likely associated with not owning the Zity car. However, heavy users appeared to develop a sense of responsibility toward the vehicles, treating them more carefully as they anticipated reusing them in the near future.

Table 3. Descriptive statistics and cross-tabulations

		Crash		No crash		p-value	Fault		Not-at-fault		p-value
Categorical variables		**# Obs**	**%**	**# Obs**	**%**		**# Obs**	**%**	**# Obs**	**%**	
Count		691	0.03	2,176,807	99.9		545	78.9	146	21.1	
Previous trips via Zity	Q1 (0-5)	235	34.0	580,851	26.7	0.000	178	32.7	57	39.0	0.148
	Q2 (6-16)	167	24.2	521,431	24.0	0.895	135	24.8	32	21.9	0.475
	Q3 (17-44)	134	19.4	533,318	24.5	0.002	112	20.6	22	15.1	0.137
	Q4 (45+)	155	22.4	541,207	24.9	0.139	120	22.0	35	24.0	0.615
Gender	Male	456	66.0	1,544,521	71.0		359	65.9	97	66.4	0.898
	Female	235	34.0	632,286	29.0	0.004	186	34.1	49	33.6	0.898
Age cohort (years)	25 and under	280	40.6	443,879	20.4	0.000	250	45.9	30	20.5	0.000
	26 and over	411	59.4	1,732,928	79.6		295	54.1	116	79.5	0.000
Time of Trip	Early morning	87	12.7	268,091	12.3	0.826	63	11.6	24	16.4	0.115
	Morning	145	21.0	522,834	24.0	0.062	113	20.7	32	21.9	0.755
	Afternoon	242	35.0	803,405	36.9	0.304	179	32.8	63	43.2	0.020
	Evening	60	8.7	199,219	9.2	0.669	47	8.6	13	8.9	0.915
	Night	157	22.7	383,258	17.6	0.000	143	26.2	14	9.6	0.000
Day of Week	Monday	87	12.6	290,296	13.3	0.564	66	12.1	21	14.4	0.462
	Tuesday	83	12.0	301,262	13.8	0.164	64	11.7	19	13.0	0.675
	Wednesday	90	13.0	314,258	14.4	0.291	69	12.7	21	14.4	0.583
	Thursday	108	15.6	331,361	15.2	0.766	80	14.7	28	19.2	0.184
	Friday	127	18.4	392,050	18.0	0.800	101	18.5	26	17.8	0.841
	Saturday	113	16.4	327,093	15.0	0.329	90	16.5	23	15.8	0.825
	Sunday	83	12.0	220,487	10.1	0.101	75	13.8	8	5.5	0.006
Numeric variables		**Crash**		**No crash**		**p-value**	**Fault**		**Not-at-fault**		**p-value**
		Mean	**Std. Dev**	**Mean**	**Std. Dev**		**Mean**	**Std.**	**Mean**	**Std.**	
Trip length (km)		11.09	14.24	9.02	8.64	0.315	11.31	14.80	10.34	11.95	0.857
Traffic (# veh/h)		2,163	1,197	2,240	1,130	0.202	2,097	1,236	2,407	1,003	0.004
Weather (l/m2)		1.27	4.17	1.14	3.78	0.820	1.22	4.05	1.45	4.59	0.753

Table 4. Logistic regression

# of obs		= 2,177,498					# of obs	= 691			
Prob > chi^2		=0.00					Prob > chi^2	=0.00			
		Crash/No crash					At-fault / Not-at-fault				
		Coefficient	Std. err.	z	p>|z|		Coefficient	Std. err.	z	p>|z|	
Previous trips	Q1 (0 to 5)	0.336	0.105	3.21	0.001	***	-0.416	0.270	-1.54	0.123	
	Q2 (6 to 16)	0.119	0.112	1.06	0.288		0.015	0.296	0.05	0.960	
	Q3 (17 to 44)	-0.124	0.118	-1.04	0.296		0.186	0.326	0.57	0.568	
	Q4 (over 45)	0	(omitted)				0	(omitted)			
Gender - Female		0.201	0.081	2.49	0.013	**	0.169	0.212	0.79	0.427	
Age – 25 and under		0.968	0.079	12.30	0.000	***	1.314	0.242	5.42	0.000	***
Time of Trip	Early morning	0.099	0.126	0.79	0.428		0.120	0.303	0.40	0.693	
	Morning	-0.044	0.105	-0.42	0.673		0.336	0.263	1.28	0.202	
	Afternoon	0	(omitted)				0	(omitted)			
	Evening	-0.184	0.147	-1.25	0.210		-0.177	0.380	-0.46	0.642	
	Night (000am-0659am)	0.351	0.106	3.31	0.001	***	1.274	0.337	3.78	0.000	***
Day of Week	Monday	-0.060	0.140	-0.43	0.665		-0.227	0.352	-0.65	0.519	
	Tuesday	-0.142	0.142	-1.00	0.316		-0.247	0.360	-0.69	0.493	
	Wednesday	-0.105	0.138	-0.76	0.449		-0.207	0.356	-0.58	0.562	
	Thursday	0.019	0.131	0.14	0.886		-0.359	0.331	-1.09	0.278	
	Friday	0	(omitted)				0	(omitted)			
	Saturday	0.012	0.131	0.09	0.925		-0.196	0.347	-0.56	0.573	
	Sunday	0.059	0.144	0.41	0.685		0.910	0.460	1.97	0.050	**
Trip length (Log km)		0.077	0.029	2.60	0.009	***	0.085	0.085	1.00	0.320	
Trip length ([Log km]^2)		0.164	0.010	15.96	0.000	***	0.062	0.034	1.83	0.067	
Traffic (# veh/h)		-0.000	0.000	-0.24	0.813		-0.000	0.000	-0.43	0.666	
Weather (l/m2)		0.008	0.009	0.85	0.396		-0.010	0.022	-0.44	0.662	
Constant		-8.760	0.162	-53.91	0.000		0.756	0.435	1.74	0.082	

*** p<0.01, ** p<0.05

Table 5. Logistic regression with interactions

# of obs		= 2,177,498					# of obs	= 691			
Prob > chi^2		.000					Prob > chi^2	.000			
		Crash/No crash					At-fault / Not-at-fault				
		Coefficient	Std. err.	z	p>|z|		Coefficient	Std. err.	z	p>|z|	
Previous trips	Q1 (0 to 5)	0.306	0.119	2.56	0.010	***	-0.427	0.269	-1.59	0.112	
	Q2 (6 to 16)	0.156	0.126	1.24	0.216		0.021	0.295	0.07	0.943	
	Q3 (17 to 44)	-0.050	0.132	-0.38	0.703		0.170	0.321	0.53	0.597	
	Q4 (over 45)	0	(omitted)				0	(omitted)			
Gender - Female		0.205	0.091	2.26	0.024	**	0.179	0.212	0.85	0.398	
Interactions	25 and under - Night	1.784	0.143	12.43	0.000	***	2.686	0.747	3.60	0.000	***
	25 and under -Rest of Day	1.114	0.100	11.07	0.000	***	1.207	0.244	4.95	0.000	***
	26 and over - Night	0.468	0.137	3.42	0.001	***	1.107	0.346	3.20	0.001	***
	26 and over - Rest of Day	0	(omitted)				0	(omitted)			
Day of Week	Monday	-0.095	0.158	-0.60	0.548		-0.196	0.350	-0.56	0.576	
	Tuesday	-0.160	0.160	-1.00	0.317		-0.221	0.359	-0.62	0.537	
	Wednesday	-0.127	0.156	-0.81	0.417		-0.198	0.353	-0.56	0.575	
	Thursday	-0.040	0.149	-0.27	0.790		-0.345	0.326	-1.06	0.289	
	Friday	0	(omitted)				0	(omitted)			
	Saturday	-0.001	0.147	-0.00	0.997		-0.230	0.345	-0.67	0.504	
	Sunday	0.170	0.155	1.10	0.273		0.939	0.459	2.05	0.041	
Trip length (Log km)		0.086	0.032	2.64	0.008	***	0.084	0.083	1.01	0.311	
Trip length ([Log km]^2)		0.171	0.011	15.37	0.000	***	0.060	0.034	1.78	0.075	
Traffic (# veh/h)		-0.000	0.000	-0.26	0.796		-0.000	0.000	-0.41	0.678	
Weather (l/m^2)		0.005	0.011	0.46	0.646		-0.012	0.022	-0.55	0.583	
Constant		-9.14	0.174	-52.5	0.000		0.875	0.415	2.11	0.035	

*** $p<0.01$, ** $p<0.05$

> *"Some customers take care of the car as if it was their own because they know that they will use it again tomorrow"*
> Zity top management member

> *"Previous experience with Zity does influence crashes. Recurrent users, those who use it to go to work or come back home, take more care of the vehicles"*
> Zity operations manager

Zity users corroborated the idea that misbehavior might explain the higher crash probability among younger drivers, particularly at night. Some interviewees pointed to the prevalence of social media videos showcasing illegal racing and reckless driving with Zity vehicles. Other Zity users reported observing groups of young people using Zity cars as makeshift bars on Friday evenings, consuming alcohol inside the vehicles. Frequent users also mentioned that their usage frequency influenced their driving behavior, as they treated the cars more carefully, knowing they would likely use the service again.

> *"I go over the bumps faster with the carsharing car. With my own car, I always slow down...Every weekend I see groups of youngsters who use Zity car as bars to drink alcohol inside and then drive off to discos or whatever"*
> Zity user 1

> *"I think some users just rent the car to play with it, accelerate, etc. This is more common among younger generations because they do not have their own cars...You know you are being charged by the minute. Unconsciously you tend to go faster"*
> Zity user 2

> *"They crashed the cars, and then it was published on social media. It is a video with over 2m views...I think you treat better the cars if you use them more frequently. At the end of the day, you want to use it whenever you want. If they are in the workshops, there are less cars in the streets"*
> Zity user 3

> *"The main reason to treat the car poorly is because it is not yours...We all have seen videos of illegal racing on social media. They tend to be very young users...I remember the first time I used a Zity car. I had never driven an electric car before. It was quite different. I drove really really careful...I have friends who barely know how to drive and instead of using their family car they prefer to use Zity in case they have an accident"*
> Zity user 4

Discussion

The results partially corroborate our initial hypotheses. The first hypothesis posited a higher crash likelihood for trips undertaken by younger and male drivers. The data support the increased risk for younger drivers (aged 25 years and under) but not for male drivers. The result obtained for young drivers is consistent with previous studies, specifically with the findings of Shaheen et al. (2016) for carsharing. Evidence from the interviews suggests that previously explored factors such as risk-taking behaviour (e.g., illegal racing or aggressive maneuvers) and lack of driving experience may contribute to the increased collision rates (Rolison et al., 2018).

Contrarily, our analysis indicates a marginally higher crash likelihood for female drivers, diverging from previous research. A potential explanation may lie in the type of crashes that occur in urban settings. According to Bingham and Ehsani (2012), there is empirical evidence that female drivers have a higher likelihood of left and right-side crashes compared to men. If a large number of the crashes recorded by Zity are of this type, this could explain why female drivers appear to have a higher likelihood of crashing. Regarding culpability, gender does not exhibit a correlation with being at fault or not. When consulted, the management of the company confirmed that they did not analyse incidents by gender but believed that the rates were similar for males and females.

The study also finds a higher crash probability during nighttime (midnight to 7 am). Previous research has shown that nighttime crashes are often associated with alcohol consumption (Keall et al., 2005) and/or driver fatigue (Horne & Reyner, 1999), both of which increase impaired driving at night. In the case of Zity, alcohol appears to play a significant role. The top management team member mentioned instances where drivers abandon their cars after a crash on Friday and Saturday nights because they prefer to be penalised by the company than being tested for alcohol by police. One customer noted that he has seen groups of young people using Zity cars as improvised bars on weekend evenings. Sleep deprivation was not mentioned during the interviews.

It is likely that multiple passengers sharing the car at night could engender peer pressure for aggressive driving (Zeyin et al., 2022), resulting in increased distraction and elevated crash rates (Doherty et al., 1998). Vandalism and illicit activities further compound the risk at night, with documented instances of Zity cars being utilised for unauthorised racing in Madrid, occasionally resulting in collisions (Lopez, 2019; Pareja, 2020). The interaction between Time of trip and Age underscores a significant increase in both crash likelihood and at-fault probability during nighttime for younger drivers, possibly due to amplified risk-taking behaviours, as indicated by Zity management.

Previous trips were also a factor in crash likelihood as the study revealed that drivers with fewer prior trips (0-5 trips) are more likely to be involved in a crash. Several factors could explain this finding. Evidence from both management and customers suggests that a lack of psychological ownership might be a key reason: Zity cars are treated worse than personal vehicles, primarily because users do not own them. Drivers with very limited use of the service may not yet have developed a sense of ownership toward the vehicle or the service, potentially leading to less careful usage patterns (Shu & Peck, 2018). However, interviewees suggested this may change as the number of trips increases. Although the development of psychological ownership falls outside the scope of this study, it is plausible that drivers who use the service more frequently begin to perceive greater benefits (Bardhi & Eckhardt, 2012) and, as a result, adopt more cautious driving behaviour. Another factor associated with the number of Previous trips could be the initial unfamiliarity with the vehicle, which may increase the likelihood of crashes (Perel, 1983; Tefft et al., 2019). For Zity, the exclusive use of automatic, fully electric vehicles may have presented additional challenges for first-time users due to their unique driving characteristics (Mechante et al., 2022). This issue was particularly evident during Zity's early years, as highlighted by the company's customer experience manager. Whether due to a lack of attachment, diminished perceived benefits, or unfamiliarity with the vehicle, fewer prior uses of the carsharing service are associated with a higher likelihood of crashes. However, this variable does not significantly affect the attribution of fault in crashes. This indicates that the factors influencing the likelihood of a crash related to prior usage (Previous trips) do not contribute to determining driver culpability.

The model includes adjustments for trip length, using kilometres driven as a proxy for risk exposure. The coefficients for kilometres driven display a U-shaped pattern, aligning partially with previous research suggesting that crash probability increases with greater exposure to risk (Massie et al., 1995; Regev et al., 2018; Segui-Gomez et al., 2011). Our findings also indicated that shorter trips are associated with a higher crash risk, which may be explained by the "low-mileage bias". This concept suggests that low-distance drivers tend to drive more frequently on local and arterial roads, which have higher traffic volumes and numerous conflict points (e.g., intersections), in contrast to high-distance drivers, who typically travel on freeways and motorways with separated lanes and fewer conflict points (Hakamies-Blomqvist et al., 2002; Langford et al., 2006). In the case of Zity, which operates exclusively within the Madrid urban area, the high crash rates for shorter trips are likely influenced by drivers' unfamiliarity with electric, automatic models, vehicles that were uncommon in Madrid at the time of the study. As highlighted by the interviewed managers, there have even been instances of crashes occurring only a few hundred metres after the trip began.

Practical Applications

Insights from this study have direct implications for road safety professionals navigating the proliferation of shared mobility providers in urban landscapes. New regulations could oblige companies to obtain customers' permission to share anonymised data about carshare use and crashes with the local authorities. Data should include among other elements, information about age, time, specific vehicle type and crash location. With this information local authorities could design targeted safety campaigns, especially addressed to the segments more likely to be involved in crashes. The company may also offer non-compulsory online training courses for new drivers to improve their driving behaviour (Horswill et al., 2023), explaining how the system works, different hazard situations and the characteristics of driving an electric car. Furthermore, providers of carsharing services might employ these findings to strengthen safety through the implementation of personalised safety communications before and after trips (Michelaraki et al., 2021) based on their driving performance measured by instruments in the car and the provision of traffic assistance (Charly & Mathew, 2024).

Strengths and limitations

This study provides new insights into carsharing based on over two million trips. This substantial sample size is a key study strength as it contributes to the robustness of the findings and reduce the likelihood of biases inherent in smaller sample sizes. Another major strength of the study is the mixed-method approach that ensures the insights from the quantitative data are qualified with the expert insights from the company representatives and experiences of the carshare users.

The present study, while comprehensive, acknowledges certain limitations. First, the analysis is constrained by the dataset's coverage: the number of covariates is limited and only crashes for which the car is taken to an external workshop for repair are considered. This limitation raises the possibility that the unaccounted crashes, albeit likely to result in minimal/no harm, might exhibit distinct characteristics explained by other variables. Second, the lack of data on drivers' prior experience with electric vehicles or other carsharing platforms precludes a thorough evaluation of the Previous trips variable's effectiveness in capturing relevant driving skills and attitudes towards the service. Third, the binary gender categorisation overlooks other gender identities, a limitation that could affect the generalisability of the findings. Fourth, the age categorisation did not differentiate older drivers and the inclusion of a separate category for drivers aged 65 and above could provide additional insights. Finally, the study's context-specific nature, conducted within a particular operator and city setting, suggests that replicating the analysis in different environments, each with unique service characteristics, urban layouts, and cultural driving norms, might yield varying results.

Conclusion and future research

Amidst the increasing significance of carsharing in urban mobility frameworks, there remains a notable paucity of research exploring the determinants of crashes within this context. This article enriches the existing corpus of knowledge by examining a novel geographical and cultural context (Madrid) and by scrutinising the impact of established demographic factors—gender and age—alongside the temporal aspects of carsharing usage. Additionally, it introduces a novel variable: the cumulative number of trips a driver has previously completed using the carsharing operator's platform. This metric potentially encapsulates a range of hitherto unobserved factors, such as user appreciation for the service, familiarity with the vehicle, and a sense of attachment to the service or the car itself. The results show that youth, nocturnal trip timing, and limited prior engagement with the carsharing platform are significantly correlated with increased likelihood of crashes. Furthermore, it provides evidence of the association of younger drivers using carsharing services at night and increased culpability in crashes. These findings offer valuable insights into the dynamics of carsharing-related crashes and provide a foundation for targeted policy interventions and safety measures tailored to this emerging mode of urban transportation.

Future research should explore the latent factors linked to Previous trips and integrate additional variables to provide a more nuanced understanding of carsharing-related crashes. A deeper examination of the psychological underpinnings of these relationships, particularly in relation to notions of ownership and perceived value of the service, could provide valuable insights. Expanding the scope of previous experience to include overall driving experience and the duration since the last carsharing usage would also enrich the analysis. Also, the fact that the variable does not seem to be correlated with culpability merits further attention. The marginally higher crash probability among women compared to men, and the absence of a correlation between this variable and culpability, warrant further investigation. Finally, exploring the interplay of cultural and vehicular factors that might account for variances in crash rates across different cities represents a valuable avenue for future research.

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Author contributions

Andres Camacho: Made a substantial contribution to the conception, design, execution or interpretation of the reported study. Jose Portela: Made a substantial contribution to the conception, design, execution or interpretation of the reported study. Jose Luis Arroyo: Methodology and double check of all the results. Carmen Valor: Qualitative part of the study, Critical review.

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Human Research Ethics Review

The study protocols were approved on 5 March 2024, by the Ethics Commission of the Doctoral Programme at the Escuela Internacional de Doctorado, Universidad de Comillas, Madrid (Approval Number: 1/50324). The the approved study protocols also included access to anonymised, non-identifiable Zity data. All interviewed subjects gave their informed consent for inclusion before they participated in the study.

Data availability statement

All necessary approvals to analyse the data and publish this paper have been obtained from the Company at the Board level. The authors used restricted-use data that cannot be released to other researchers. However, we agree to provide information to other researchers as to how the data were curated, as well as all methodological decisions.

Conflicts of interest

The author team declares that the first author has acted as vice-president of the Board of Directors of Zity from November, 2019 to December, 2023. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The authors declare that there are no conflicts of interest.

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