Hindawi
Journal of Advanced Transportation
Volume 2018, Article ID 9543787, 7 pages
https://doi.org/10.1155/2018/9543787

Research Article

Motorcyclist Is the Right-of-Way Violator: A Population-Based Study of Motorcycle Right-of-Way Crash in Taiwan

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Received 3 January 2018; Revised 12 June 2018; Accepted 24 June 2018; Published 17 July 2018

Academic Editor: Richard S. Tay

The most typical and catastrophic car-motorcycle crash occurs when a car manoeuvres into the path of an approaching motorcycle at an intersection, which involves a car driver violating motorcycle's right of way (ROW). In Taiwan, however, motorcyclists are frequently the ROW violator—they are observed to frequently infringe upon the ROW of oncoming vehicles at intersections. Such a ROW crash in which a left-turn motorcyclist crosses in front of approaching traffic appears to be a safety problem in terms of its frequency and accident consequence. Using the National Taiwan Crash Database, the present study estimates a logistic regression model to predict the likelihood of an approach-turn motorcycle-turning crash (relative to a car-turning crash). Results indicate that given a ROW crash where the rider was female, old, drunk, unlicensed, riding a moped, and on a NBU roadway, the likelihood of a motorcycle-turning crash tends to increase. Our study contributes to the existing motorcycle safety research by reporting the determinants of the unique crashes in which the motorcyclist is the ROW violator.

1. Introduction

Past studies [1–5] have identified motorcycle right-of-way (ROW) crash as the most typical and catastrophic car-motorcycle crash that occurs at an intersection. The crash type involves a car maneuvering into the path of an approaching motorcycle, primarily due to motorcycle's poor conspicuity or car driver's speed/distance judgment error. In Taiwan, car-motorcycle ROW accidents appear to be comparatively different from those in western countries: in western countries the turning motorist is frequently the ROW violator, while in Taiwan motorcyclists are the ones that have been frequently observed to violate the ROW of approaching automobiles at intersections [6, 7].

To curb the ROW violation by motorcyclists, an engineering measure, a hook-turn area, has been implemented in Taiwan for deterring motorcyclists from turning directly in front of other cars at intersections. Motorcyclists intending to make a left turn are directed to wait at the hook-turn area and then proceed to their intended directions. Pai et al. [6] conducted an observational study in Taiwan and examined the contributory factors to motorcyclists' unwillingness to use the hook-turn area. Pai et al. [6] have suggested that one of the contributory factors to motorcyclists frequently violating ROW of oncoming vehicles in Taiwan could be that motorcycles appear to significantly outnumber other motorised vehicles. Motorcyclists could therefore be a self-selected group of road users with greater road priority, leading to their unwillingness to yield ROW to oncoming vehicles. Such a phenomenon appears to be different in western countries where motorists do not expect to see motorcyclists: the detection failure was due to the fact that motorcycles are infrequently confronted in traffic [8, 9]. According to the National Traffic Crash Dataset for the years 2003-2014, the ratio of the number of approach-turn motorcycle-turning crash to the number of approach-turn car-turning crash in Taiwan is 1:4.6, compared with 1:25 in the US [10] and 1:16 in the UK [11], respectively. It is evident here that approach-turn car-turning crashes are prevalent in western countries, while approach-turn motorcycle-turning crashes are also common in Taiwan. Also, according to the National Traffic Crash Dataset in Taiwan for the years

2003-2014, fatality rate was higher to motorcyclists when they were ROW violator, compared with when motorists were ROW violator (1.48% vs 0.53%).

Although the crashes involving left-turning motorcycle that violated the ROW of oncoming vehicles are less in numbers, they need more attention than their counterpart (a left-turning car violated the ROW of oncoming motorcycles). To the authors' knowledge, there seems to be few studies that have attempted to address the safety problems arising from the unique crash type. The primary objective of this study is to examine what variables predict a crash being an approach-turn motorcycle-turning crash rather than an approach-turn car-turning crash. The variables examined include demographic variables, vehicle attributes, temporal factors, and road/environmental characteristics, all of which have been reported in past studies to affect motorcycle ROW crashes [5, 10].

2. Method

2.1. Data Source. The data source used in the present study is a police-reported crash dataset (called the National Traffic Crash Dataset). The data are recorded by the National Police Agency, Taiwan. Once an accident has been reported to police, qualified and experienced police crash investigators complete crash report forms comprising three files called accident, vehicle and victim, and contributory factor files.

Accident files contain general information regarding the times and dates of crashes; weather, road, and lighting conditions; and road type. Furthermore, vehicle and victim files are used to record information regarding vehicles; riders and victims, such as age, sex, and injury severity; vehicle type; the first point of vehicle impact; and vehicle manoeuvres. Injury severity is classified into three levels: fatal, injury, and property damage only. Those victims who die within 24h as a result of an accident are classified as fatal injuries; injuries are defined as injuries sustained by victims who had mild or severe injuries but did not die within 24h after the accident; and property damage only refers to damage only to their property because of the accident. Property-damage-only data are excluded in this study as the data were deposited by local police agencies and not acquired by the National Police Agency.

The current research analysed the National Traffic Crash Dataset for the period 2003–2014. After excluding missing data such as genders and crash dates and repeated cases were also removed, there are a total of 19926 valid cases for approach-turn crashes. Of the 19926 approach-turn crashes, there are 16354 cases in which a left-turning car violated the ROW of oncoming motorcycles and 3572 cases in which a left-turning motorcycle violated the ROW of oncoming vehicles.

2.2. Definition of Variables. The examined demographic data for the patients were sex (male and female), age (four groups: <18, 18-40, 41-64, >65), license (licensed and unlicensed), and alcohol use (yes and no). Those aged less than 18 are generally identified as teenagers that cannot ride motorcycles or drive cars legally. Those aged 65 or above are generally identified as the elderly. As for age intervals 18-40 and 41-64, we simply classify the remaining ages into two even age intervals. Vehicle attributes were engine size (three levels: ≤50cc, 51-250cc, 251cc, or above), and crash partner (taxi, heavy vehicle, car, and others). Alcohol-use data were obtained by police who conduct breath test or followup for blood test in hospital.

Two temporal factors, crash time (daytime, and evening/night) and weekdays (weekday and weekend), were examined. Road and environmental factors comprised several variables—location (NBU: nonbuilt-up roadways with speed limits 51km/h or above, and BU: built-up roadways with speed limits 50km/h or below) and curvature (straight road, horizontal curvature, and vertical curvature: uphill/downhill road).

The examined approach-turn crashes are classified into two crash types and based on which was the left-turning vehicle between a motorcycle and a car. An approach-turn motorcycle-turning crash is defined as a crash in which a left-turning motorcycle collides with an oncoming car (including car, taxi, and bus/coach). An approach-turn car-turning crash is classified for an accident where a left-turning car collides with an oncoming motorcycle (see Figure 1 for a schematic illustration of these two ROW crash types).

2.3. Statistical Analysis. Distribution of two types of approach-turn crashes by a set of variables (e.g., human attributes, environmental factors, and vehicle characteristics) is reported. Chi-square tests are conducted for comparing between the two types of approach-turn crashes. Using chi-square tests, the variables found to be associated with the outcome ($p<0.05$) were then incorporated into the stepwise logistic regression models. VIF (variance inflation factor) was conducted to assess multicollinearity among the variables.

Other alternative models, such as a mixed logit model, were estimated to ascertain whether they perform better than the logistic regression models. For instance, we firstly assumed all parameters to be random and then evaluated their estimated standard deviations by using a zero-based (asymptotic) t-test for each parameter. For specifying the type of the distribution, various distributions such as a normal, lognormal (which restricts the effect of the estimated parameter to be positive or negative), triangular, or uniform distribution were assumed to determine proper densities for random parameters. All parameters were assumed to have linear effects across the observations because the estimated standard errors were not statistically different from 0.

3. Results

Table 1 summarises the human attributes, environmental factors, and vehicle characteristics of the two approach-turn crash types that occurred between 2003 and 2014. Based on the □χ^2 statistics, the factors that are most associated with an approach-turn MC-turning crash include female, motorists aged less than 20, the elderly motorcyclist, unlicensed riders, intoxicated motorist/rider, daytime, moped, NBU roadway, horizontal/vertical curvature, heavy vehicle, and weekend.

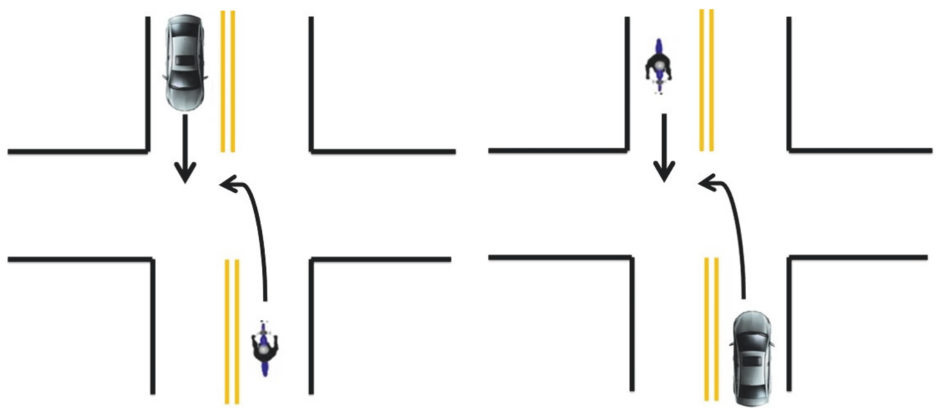

Figure 1: Schematic diagram of the two ROW crash types ((a) approach-turn motorcycle-turning crash; (b) approach-turn car-turning crash).

Looking at the specific results of the logistic regression model in Table 2, the indicator variable for female motorcyclists was significant for an approach-turn motorcycle-turning crash—it appears that given a ROW crash where the motorcyclist was a female, the likelihood of a ROW crash being a motorcycle-turning crash increases (adjusted odds ratio [AOR]=1.44; confidence interval [CI]=1.33-1.57). The effect of the elderly motorcyclist (aged 60 or above) was found to be significant, suggesting that given a ROW crash in which the motorcyclist was the elderly, it is more likely a motorcycle-turning crash (AOR=3.11; CI=2.77-3.49).

The parameter for the indicator variable for unlicensed motorcyclists appears to be positive and significant, implying that given a ROW crash where the motorcyclist was unlicensed, it is more likely a motorcycle-turning crash (AOR=1.62, CI=1.45-1.82). Regarding the effect of alcohol use, both motorists and motorcyclists under the influence of alcohol were found to be the determinants of the crash. It appears here that given a ROW crash where motorists and motorcyclists were drunk, the likelihoods of a motorcycle-turning crash increased by 38% and 159% (AORs=1.38 and 2.59, respectively). Mopeds appear to be a determinant of an approach-turn motorcycle-turning crash—given a ROW crash where a moped was ridden (relative to a motorcycle with engine size of 51cc-249cc), the likelihood of a motorcycle-turning crash increases to 48% (AOR=1.48, CI=1.33-1.65).

The indicator variable for evening/early morning hours suggests that if the ROW crash occurred during these hours, the likelihood of a motorcycle-turning crash decreases (AOR=0.67. CI=0.62-0.73). As for roadway variables, the effect of NBU was found to be significant, suggesting that given a crash that occurred on nonbuilt-up roads, it is more likely a motorcycle-turning crash (AOR=1.38, CI=1.19-1.56). The indicators variables for horizontal or vertical curvatures appear to be significant. The variables suggest that if the ROW crash occurred on these locations, the likelihoods of a motorcycle-turning crash increase to 87% (for horizontal curvature) and 90% (for vertical curvature).

The last finding for a motorcycle-turning crash relates to the effect of weekend. Weekend appears to be a contributory factor to a motorcycle-turning crash and the result suggests that given a ROW crash occurring on weekends, it tends to be a motorcycle-turning crash (AOR=1.10, CI=1.00-1.20).

4. Discussion and Conclusions

Using logistic regression models, the current research has uncovered the determinants of the approach-turn motorcycle-turning accidents that appear to have an impact on motorcyclist safety in terms of crash occurrence and consequence. The present paper adds to the existing motorcycle safety research by revealing several contributory factors to the crash type. Recommended interventions aimed at improving motorcycle safety at intersections, based on our results, would include curbing motorcyclist's failure to yield ROW through enforcement efforts as well as public information and safety education programmes. For instance, safety education programmes can be directed towards certain groups of motorcyclists such as female/old riders who were found to result in an increased likelihood of a motorcycle-turning crash. In addition, prosecutions should be enforced towards unlicensed and intoxicated riders.

Several important empirical findings merit further discussions here. First, the elderly riders were found to be associated with the motorcycle-turning crashes. Past studies of car-car crashes at intersections have established that older motorists tended to be over-involved in crashes while turning left across oncoming traffic [12]. Age-related physical and cognitive declines were identified to be the contributory factors to the crash type. Zhou et al. and Pollatsek et al. [7, 13, 14] reported that older drivers may exhibit a relative insensitivity to vehicle approach speed in left-turn manoeuvres across traffic—they generally overestimate the speed of vehicles travelling at low speeds and underestimate the speed of those travelling much faster, thereby contributing to the ROW crashes. It seems evident here that the aged-related impairment and decline are not only applied to older motorists (in western countries) but also older motorcyclists

Table 1: Characteristics of the independent variables and two approach-turn crash types, 2003-2014.

	Approach-turn Car turning		Approach-turn MC turning		χ^2 test
	N	%	N	%	p-value
Total	16,354	82.07	3,572	17.93	
Driver gender					0.64
Male	12,817	82.01	2,812	17.99	
Female	3,537	82.31	760	17.69	
Motorcyclists gender					<.0001
Male	10,900	83.90	2,092	16.10	
Female	5,454	78.66	1,480	21.34	
Driver age					<.0001
<18	8	72.7	3	27.3	
18-40	8362	80.2	2067	19.8	
41-64	7336	83.8	1417	16.2	
>65	648	88.4	85	11.6	
Motorcyclists age					<.0001
<18	573	80.8	136	19.2	
18-40	11743	86.4	1842	13.6	
41-64	3416	75.6	1101	24.4	
>65	622	55.8	493	44.2	
License					
Drivers					0.47
Licensed	15,800	82.01	3,467	17.99	
Unlicensed	432	83.24	87	16.76	
Motorcyclists					<.0001
Licensed	14,463	83.62	2,834	16.38	
Unlicensed	1,696	71.68	670	28.32	
Alcohol use					
Drivers					0.04
No	15,758	82.16	3,422	17.84	
Yes	222	77.35	65	22.65	
Motorcyclist					<.0001
No	15,667	82.78	3,258	17.22	
Yes	261	67.44	126	32.56	
Occurring during					<.0001
Daytime	10,181	80.11	2,528	19.89	
Evening/night	6173	85.53	1044	14.47	
Engine size					<.0001
251cc or above	78	92.86	6	7.14	
51-250cc	14,348	83.39	2,857	16.61	
Up to 50cc	1,928	73.11	709	26.89	
Occurring on BU roadways (up to 50km/h)					<.0001
NBU	1,204	75.68	387	24.32	
BU	15,150	82.63	3,185	17.37	
Occurring on roadways with vertical or horizontal curvature					<.0001
horizontal	255	68.55	117	31.45	
vertical	41	69.49	18	30.51	
Straight	16,058	82.37	3,437	17.63	
Vehicle types involved					0.02
Taxi	1,514	84.68	274	15.32	
Heavy vehicle	2726	81.23	630	18.77	
Car	12,024	81.96	2,647	18.04	
Others	90	81.08	21	18.92	

Table 1: Continued.

	Approach-turn Car turning		Approach-turn MC turning		χ^2 test
	N	%	N	%	p-value
Occurring on weekends or weekdays					0.01
Weekday	12,318	82.47	2,619	17.53	
Weekend	4,036	80.90	953	19.10	

Table 2: Adjusted ORs (AORs) of approach-turn motorcycle-turning crashes, 2003-2014.

	B	S.E.	Wald Chi-Square	AOR(95%CI)_Stepwise
Motorcyclist gender				
Male (ref.)	---	---	---	1.00
Female	0.35	0.04	84.15	1.40*(1.29~1.52)
Driver age				
<18	0.42	0.68	0.38	1.23(0.25~5.98)
18-40 (ref.)	---	---	---	1.00
41-64	-0.25	0.04	42.17	0.78*(0.72~0.84)
65+	-0.63	0.12	28.88	0.49*(0.39~0.63)
Motorcyclist age				
<18	0.41	0.10	17.63	1.07(0.85~1.35)
18-40 (ref.)	---	---	---	1.00
41-64	0.72	0.04	283.70	1.73*(1.58~1.89)
65+	1.62	0.07	615.37	4.31*(3.75~4.96)
License				
Motorcyclist				
licensed (ref.)	---	---	---	1.00
Unlicensed	0.70	0.05	196.24	1.59*(1.40~1.81)
Alcohol use				
Driver				
No (ref.)	---	---	---	1.00
Yes	0.30	0.14	4.42	1.45*(1.07~1.95)
Motorcyclist				
No (ref.)	---	---	---	1.00
Yes	0.84	0.11	58.43	2.36*(1.87~2.98)
Occurring during				
Daytime (ref.)	---	---	---	1.00
Evening/night	-0.38	0.04	91.43	0.68*(0.63~0.75)
Engine size				
251cc or above	-0.95	0.42	5.03	0.40*(0.16~0.99)
51-250cc (ref.)	---	---	---	1.00
Up to 50cc	0.61	0.05	160.44	1.41*(1.27~1.57)
Occurring on BU roadways (50km/h or below)				
NBU	0.42	0.06	47.50	1.35*(1.18~1.55)
BU (ref.)	---	---	---	1.00
Occurring on roadways with vertical or horizontal curvature				
Horizontal	0.76	0.11	45.04	1.81*(1.41~2.32)
Vertical	0.70	0.28	6.12	1.84(0.99~3.41)
Straight (ref.)	---	---	---	1.00
Occurring on weekends or weekdays				
Weekday (ref.)	---	---	---	1.00
Weekend	0.10	0.04	6.25	1.09(0.995~1.19)

*p<0.01; Hosmer and Lemeshow Goodness-of-Fit statistics: chi-square=6.4379 with 7 DF, yielding a p value of 0.5983.

in crashes while turning left across oncoming traffic (in Taiwan).

Second, the likelihood of a motorcycle-turning crash tends to increase given a ROW crash in which the rider was unlicensed. Such a finding is explicable if one appreciates that unlicensed riders can be inexperienced riders and their navigating ability in traffic may not be as advanced as licensed riders; and they are more likely risk-taking riders, rendering them crossing the street recklessly. Our reasoning here is supported by Chang and Yeh [15] who concluded that unlicensed riders can be inexperienced riders and were more likely to disobey traffic regulations.

Thirdly, while alcohol use by riders was identified as the cause of crash, the likelihood of a motorcycle-turning crash increases. It seems evident here that intoxicated riders can be inattentive when intersecting with oncoming vehicles, which is in line with Kasantikul et al. [16] who reported that intoxicated riders were far more likely to be inattentive to traffic just before they crashed, and to be the primary or sole cause of the accident. Certainly prosecuting drink and drive/ride may constitute effective countermeasures for reducing motorcycle accidents in general but motorcycle ROW crashes in particular.

Fourthly, given a ROW crash where mopeds (engine size of 50cc or below) were involved, the likelihood of a motorcycle-turning crash tends to increase. Reasons for such an effect may centre on the possibility that moped riders can be young riders being more likely to have risk-taking behaviours when intersecting with oncoming cars. Our reasoning here can be supported by Rutter and Quine [17] who concluded that crashes involving young riders were associated with certain patterns of behaviours such as a willingness to break the law and violate the rules of safe riding.

Finally, NBU roadways were found to be associated with a motorcycle-turning crash. The finding seems to be reasonable as police enforcement is less strict/frequent on NBU roadways compared with that on BU roadways. Motorcyclists, as a result, were more likely to execute a left-turn manoeuvre by not using the hook-turn area [5]. It is also possible that motorcycle speed would play an important in such a turning crash—it is likely that motorcyclist would travel faster on NBU roadways and as a result they are more likely to have reckless turning manoeuvres when intersecting with oncoming vehicles. Our conjecture here needs to be confirmed with speed data that are in general not available in police-reported crash data. In examining motorcycle's speed in approach-turn crashes where motorcycle's ROW was violated by turning cars, past studies [5, 10, 18–20] have concluded that motorcycle's speed tended to be higher. Coupled with the findings of these studies, the current research suggests that from a policy perspective, controlling motorcycle speed on a roadway with higher speed limit should therefore be beneficial in curbing ROW crashes (regardless of whether motorcyclist is blamed for ROW violation).

There are a few intrinsic research limitations in the current research. Similar to past studies relying on police-reporting crash data, the most obvious research limitation stems from the data that are not available in the database. While the National Traffic Crash Dataset provides a rich source of some variables, several other important factors are not readily available, including, for instance, motorcycle speed, more detailed geometric factors, other rider attributes (experience, education level, and fitness to ride), etc., all of which have been reported in literature [5] to affect motorcyclists' ROW violation.

It should be emphasised here that available studies (including the present paper) of motorcycle's ROW violation have just started to scratch the surface on the crucial issue in that motorcyclists infringing upon the ROW of approaching vehicles at intersections cause a safety problem to other road users and motorcyclists themselves. Detailed data (for instance, behavioural mechanism/intention data that can only be collected through an observational study and a questionnaire survey) would provide additional insights into motorcycle's ROW crashes. This can be the most fruitful for future research that may also further investigate such a problem in other motorcycle-dominated countries, as well as countries where recent fuel crises lead to a rapid increase in modal shift from cars to motorcycles, e.g., Brussels, Belgium [21] and Paris, and France [22].

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Ethical Approval

No individual patient or casualty can be identified and, therefore, our study was exempted from review by an institutional review board (IRB #201409033).

Conflicts of Interest

The authors would like to confirm that the received funding does not lead to any conflict of interests regarding the publication of this manuscript. The authors also confirm that there are no other possible conflicts of interest in the manuscript.

Acknowledgments

The research was funded by the research grants from Ministry of Science and Technology Taiwan (105-222-E-038 -013-MY3), and the Health Promotion Administration, Ministry of Health and Welfare, Executive Yuan, Taiwan (E1030909-104).

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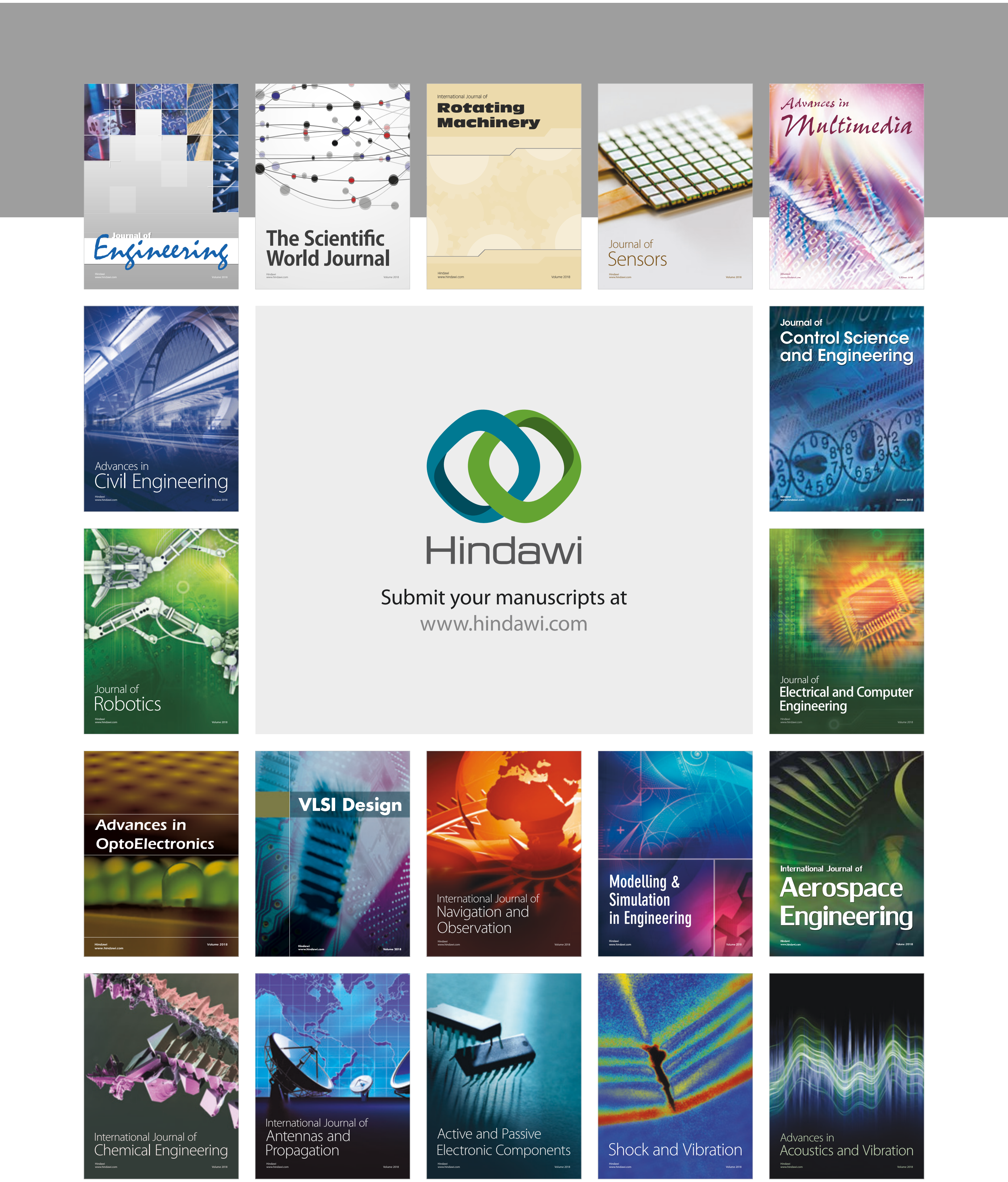
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