COMPARATIVE ANALYSIS OF MOTORIZED AND NON-MOTORIZED VEHICLE CRASHES AND CASUALTIES IN BANGLADESH

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ABSTRACT

Road traffic crashes constitute a major public health and socio-economic challenge in Bangladesh, where heterogeneous traffic conditions and rapid motorization have created an exceptionally high fatality risk, particularly for vulnerable road users (VRUs). This study presents an 18-year comparative analysis (1998–2015) of accident trends and casualty severity involving motorized vehicles (MV) and non-motorized vehicles (NMV) in Bangladesh. The analysis period was selected because 2015 represents the last year with a complete, nationally consistent and validated accident dataset available from the Accident Research Institute (ARI), BUET, prior to major changes in data collection protocols and reporting structures. Secondary accident records were obtained from the ARI database and analyzed using longitudinal trend analysis and descriptive statistics. Accident involvement and casualties were categorized into fatal, grievous, simple, and collision outcomes. Case Fatality Rate (CFR) was employed as the primary indicator of accident severity. The results show that motorized vehicles accounted for 85.6% of total accidents, with buses and motorcycles emerging as dominant contributors. Despite a decline in NMV accident frequency after 2008 due to regulatory restrictions, NMV-related crashes retained a high CFR, indicating persistent structural vulnerability. The findings highlight that reductions in accident frequency do not necessarily correspond to reductions in severity and emphasize the need for speed management and physical traffic segregation to mitigate the extreme risks associated with mixed traffic conditions in Bangladesh.

Keywords: *Road Accidents, Traffic Casualties; Vulnerable Road Users (VRU); Accident Severity; Injury Epidemiology.*

1. INTRODUCTION

Bangladesh currently contends with a severe and persistent road safety crisis, which undermines the nation's broader socio-economic progress (The World Bank, 2020a). Despite government efforts, Bangladesh has one of the world's highest road fatality rates per vehicle, driven by rapid motorization, mixed traffic conditions, and limited infrastructure (Akter & Hossain, 2023; Asian Transport Observatory, 2025). Road traffic crashes (RTCs) constitute a leading cause of death among young adults aged 15 to 29 in South Asia (The World Bank, 2020b). Official records indicate high mortality, yet World Health Organization (WHO) estimates suggest the true annual fatality figure is significantly higher, potentially reaching 32,000 deaths in 2021 (Asian Transport Observatory, 2025; Dhaka Tribune, 2025). The mortality rate of 15.3 per 100,000 population and, more critically, the distinction of having the highest fatality rate per registered vehicle globally (102 deaths per 10,000 motor vehicles) highlights an environment of profound systemic risk (Islam et al., 2023).

The financial burden imposed by these crashes is staggering, translating to estimated economic losses equivalent to 3% to 5% of the Gross Domestic Product (GDP) annually in low- and middle-income countries. The core challenge lies not merely in the volume of vehicles but in the operational environment. South Asia accounts for 23% of global road crash deaths despite housing only 10% of the world's motorized fleet (The World Bank, 2020b). This disproportionate risk is largely generated by the chronic instability of heterogeneous traffic environments, where vehicles of widely divergent speeds, masses, and protection levels—ranging from high-speed buses to delicate rickshaws—must coexist on shared infrastructure (Zahra & Sukor, 2024).

The infrastructure in metropolitan areas of Bangladesh facilitates an unavoidable coexistence between high-speed motorized vehicles (MVs) and low-speed non-motorized vehicles (NMVs). This mixed flow inherently places the majority of road users at extreme risk. Vulnerable Road Users (VRUs)—a category encompassing pedestrians, bicyclists, motorcyclists, and passengers of structurally unprotected NMVs—account for nearly 70% of all road traffic fatalities in Bangladesh (Zahra & Sukor, 2024). Heavy vehicles (buses, trucks) also figure heavily in fatal crashes; in 2012 buses and trucks were implicated in ~68% of crash events (Rahman et al., 2014)

Within the VRU category, two distinct groups dominate accident concerns. First, non-motorized transport, particularly the cycle rickshaw, remains a vital mode of urban transit but possesses a structure described as light, delicate, and vulnerable (Sufian & Ahsan, 2014; Akter & Hossain, 2023). This structural fragility makes NMV occupants and pullers highly susceptible to lethal outcomes upon collision with high-mass MVs, which can create devastating kinetic energy disparities (Atombo et al., 2023). Studies confirm that lack of knowledge about traffic rules among NMV pullers and the sheer speed difference with MVs are primary factors contributing to NMV accidents (Sufian & Ahsan, 2014). Rozars et al. (2025) report that motor vehicle drivers constituted 58% of injury victims in a high-risk zone, while cyclists/rickshaw pullers made up ~23%.

Second, motorcycles, while motorized, are universally classified as VRUs due to the complete lack of protective structure and high exposure of the rider (Zahra & Sukor, 2024). The rapid motorization process in Bangladesh has seen the motorcycle become a dominant fixture in crash statistics, commanding 26.8% of total accidents with an extremely high fatality rate of 83 to 84 deaths per 100 accidents (Rozars et al., 2025; Saha et al., 2025). The surge in motorcycle usage, often driven by the desire to circumvent worsening urban congestion, introduces high-speed elements into an already volatile environment, shifting the burden of VRU risk toward this increasingly popular, yet exposed, mode.

Previous academic investigations into road safety in Bangladesh and South Asia have consistently highlighted the heightened risk to unprotected road users. Research focusing on high-risk corridors in Dhaka established the city's pronounced fatality risk due to excessive congestion and high vehicle volume (The World Bank, 2020a). Early analyses of traffic accidents in Dhaka determined that fatal

accidents were dominant (69%) and that hit-pedestrian crashes accounted for 60% of collision types, emphasizing the conflict between vehicles and pedestrians/VRUs (Hoque et al., 2014). Similar patterns were observed in regional metropolises, where heavy vehicles striking pedestrians and bicyclists accounted for the majority of fatalities (Fazio & Tiwari, 1995).

Specific studies on motorcycles noted their increasing contribution to total crashes, suggesting that even with a modal share of under 2% in Dhaka, motorcycles accounted for approximately 10% of total crashes (T. Akter & Pervaz, 2019). Research exploring NMV safety established the inherent lethality of NMV-involved accidents, with nearly 67% resulting in fatality, a rate comparable to those involving heavy motor vehicles. This earlier research demonstrated that when rickshaws are involved in collisions, the perpetrators are frequently high-mass MVs: 32% of cases involved a bus, and 25% involved heavy trucks (Sufian & Ahsan, 2014).

While existing scholarship confirms the high risk faced by both motorized and non-motorized VRUs, a comprehensive, longitudinal study quantifying the direct, temporal comparison of accident involvement and, critically, the Case Fatality Rate (CFR) across the MV and NMV categories has been largely absent. Such a comparison over an 18-year period is crucial for understanding how rapid motorization and localized urban policy interventions have differentially impacted risk and severity for distinct vehicle classes, providing essential evidence for structural policy reform.

Based on the identified knowledge gap, this study is designed to achieve several key objectives. First, it aims to conduct a longitudinal analysis covering the period from 1998 to 2015 to compare the annual frequency and proportional involvement of motorized and non-motorized vehicles in road traffic accidents across Bangladesh. Second, it seeks to quantitatively compare casualty severity distributions—categorized as fatal, grievous, and simple—and to calculate the Case Fatality Rate (CFR) for incidents involving both motorized and non-motorized vehicles. Third, the study intends to analyze the temporal evolution of accident contributions by assessing the impacts of major policy changes, such as restrictions on non-motorized vehicles, and the effects of rapid motorization, particularly the exponential increase in motorcycle registrations. Finally, the research aims to provide evidence-based recommendations for policymakers, focusing on the implementation of mandated speed management measures and the development of infrastructural segregation strategies to reduce the differential risks faced by these two crucial vehicle user groups.

2. METHODOLOGY

2.1 Research Design and Data Sources

This research utilizes a quantitative, longitudinal comparative study design, analyzing secondary accident data spanning an 18-year period from 1998 to 2015. The study period was selected because 2015 represents the last year for which the Accident Research Institute (ARI), BUET provides a complete and consistently structured national accident dataset, ensuring methodological uniformity and longitudinal comparability across all years analyzed. The primary data sources include:

- **Accident Research Institute (ARI), BUET:** National accident databases (MAAP) maintained by ARI, BUET, covering police-reported crashes in urban and rural Bangladesh (1998–2015). ARI records categorize vehicles involved, injury severity, collision type, and location.
- **Bangladesh Road Transport Authority (BRTA):** Annual vehicle registration statistics and crash summaries to estimate vehicle fleets and to cross-check accident trends (BRTA statistical reports, 2010–2023) (*BRTA*, 2025).
- **World Health Organization (WHO):** Global Status Reports on Road Safety (2018, 2022) for national estimates and methodological benchmarks (World Health Organization, 2019).
- **Published Reports and Journals:** Peer-reviewed studies and credible reports (e.g. Asian Transport Observatory (2025)) provided contextual data on crash fatalities, vulnerable road user proportions, and GDP impacts of crashes.

ARI accident records were extracted in spreadsheet format and screened for completeness and consistency. Only officially validated records were retained to avoid duplication and reporting inconsistencies. Relevant BRTA and WHO statistics (e.g., registered vehicles, population, GDP) were compiled for contextual interpretation rather than direct rate calculation. All datasets were aligned temporally to ensure year-by-year consistency throughout the analysis.

2.2 Data Categorization and Aggregation

For the purpose of comparative analysis, all accident records were systematically arranged and categorized before statistical analysis. After initial screening, accident data were first organized year-wise (1998–2015) to maintain temporal consistency across the study period. Each accident record was then classified based on the type of vehicle involved, following the standard definitions used by the Accident Research Institute (ARI).

Motorized Vehicles (MV) included all engine-powered transport modes, specifically buses, trucks, private passenger cars, tempos, and motorcycles. Non-Motorized Vehicles (NMV) comprised human-powered transport modes, including cycle rickshaws, bicycles, and pushcarts. Where multiple vehicle types were involved in a single accident, the accident was counted under each relevant vehicle category to reflect involvement-based exposure, consistent with ARI reporting practice.

Accident counts represent the annual number of reported incidents involving each vehicle category. Casualties associated with these accidents were then arranged according to ARI's severity classification system: Fatal, Grievous Injury, Simple Injury, and Collision (property damage only). Each casualty record was linked to its corresponding vehicle category and year to enable year-wise aggregation of severity outcomes. For severity-focused analysis, Simple Injury and Collision cases were retained alongside Fatal and Grievous categories to allow calculation of total casualties. This arrangement was necessary to compute the Case Fatality Rate (CFR), defined as the ratio of fatal casualties to total casualties for each vehicle category. Annual totals and percentage shares were subsequently calculated to facilitate direct comparison between motorized and non-motorized vehicles across the entire study period.

2.3 Statistical Analysis and Metrics

The analytical approach centered on time-series observation and comparative descriptive statistics:

1. **Longitudinal Trend Analysis:** Annual data for MV and NMV involvement were analyzed to visualize and quantify temporal changes. This was essential for observing the impacts of national events, economic growth, and specific regulatory interventions, such as metropolitan restrictions on rickshaws.
2. **Comparative Accident Volume:** The proportion of MV-involved accidents versus NMV-involved accidents was calculated annually to establish the relative exposure of each category to crash risk.
3. **Case Fatality Rate (CFR) Calculation:** CFR was utilized as the standard quantitative measure of accident lethality, allowing for a direct comparison of risk profiles between the two heterogeneous categories.

This metric provides a robust indicator of how frequently an accident involving a specific vehicle type results in the death of a victim. The analysis assumes that the reported casualties are directly attributable to the accidents involving the respective vehicle categories reported in the database.

2.4 Data Transformation and Visualization

The raw accident data detailing MV and NMV involvement and casualty severity were synthesized into comparative figures, prepared with OriginPro 2024 software, to facilitate cross-modal analysis. The use of synthesized tables ensures that the complex longitudinal data is presented in a structured format suitable for direct comparison and interpretation of the differential risks inherent in Bangladesh's traffic system.

3. RESULTS AND DATA ANALYSIS

3.1 Accident Frequencies: Motorized vs Non-Motorized

Table 1. Comparison of Motorized and Non-Motorized Vehicle Accidents by Year (1998-2015)

Year	No. of Accidents												
	Motorized Vehicles							Non-Motorized Vehicles					Total No. of Accidents
	Bus	Truck	Car	Tempo	Motorcycle	Total	Percentage (%)	Rickshaw	Bicycle	Pushcart	Total	Percentage (%)	
1998	881	65	339	309	179	1,773	80.63	275	125	26	426	19.37	2,199
1999	1,125	101	292	307	221	2,046	81.94	268	163	20	451	18.06	2,497
2000	1,112	169	253	292	242	2,068	81.71	264	183	16	463	18.29	2,531
2001	849	105	176	173	200	1,503	82.13	176	143	8	327	17.87	1,830
2002	1,181	143	307	208	243	2,082	83.28	244	163	11	418	16.72	2,500
2003	1,291	144	336	187	271	2,229	84.18	263	146	10	419	15.82	2,648
2004	1,209	146	268	171	230	2,024	85.98	205	115	10	330	14.02	2,354
2005	1,031	148	220	117	235	1,751	87.55	142	96	11	249	12.45	2,000
2006	1,218	182	184	167	320	2,071	84.98	200	146	20	366	15.02	2,437
2007	1,315	163	195	197	338	2,208	85.02	201	167	21	389	14.98	2,597
2008	1,220	158	238	174	435	2,225	87.67	187	107	19	313	12.33	2,538
2009	827	136	171	117	377	1,628	87.90	120	94	10	224	12.10	1,852
2010	686	136	149	88	355	1,414	88.32	99	84	4	187	11.68	1,601
2011	532	127	115	92	321	1,187	86.64	98	75	10	183	13.36	1,370
2012	540	87	91	89	345	1,152	91.57	60	41	5	106	8.43	1,258
2013	449	96	81	67	322	1,015	89.90	69	41	4	114	10.10	1,129
2014	460	109	71	39	241	920	88.63	61	55	2	118	11.37	1,038
2015	490	99	62	51	256	958	98.76	5	2	5	12	1.24	970
Total	**16,416**	**2,314**	**3,548**	**2,845**	**5,131**	**30,254**	**85.59**	**2,937**	**1,946**	**212**	**5,095**	**14.41**	**35,349**

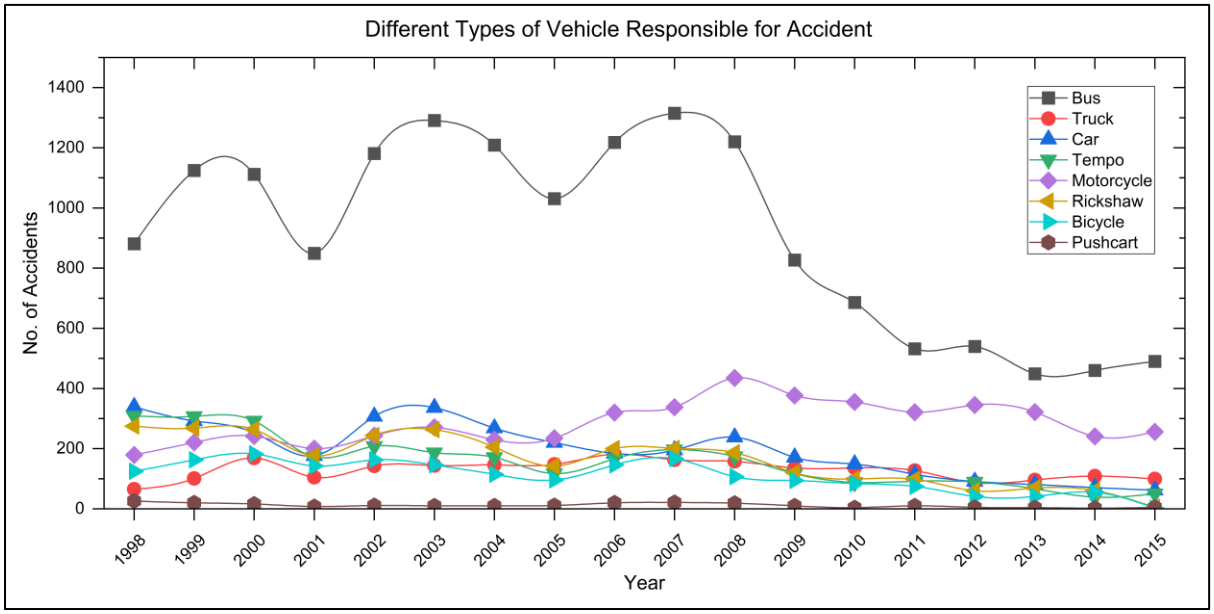

Figure 1: Different types of vehicles responsible for accident

Table 1 presents a comparative analysis of road accidents involving motorized and non-motorized vehicles over an 18-year period from 1998 to 2015. The data are categorized by vehicle type and year, showing the number of accidents attributed to each vehicle group and their respective percentages of the total annual accidents. For motorized vehicles, the table includes buses, trucks, cars, tempos, and

motorcycles. The total number of accidents involving these vehicles remained consistently higher than those involving non-motorized vehicles throughout the study period. For instance, in 1998, motorized vehicles accounted for 1,773 accidents (80.63% of total accidents), while non-motorized vehicles—such as rickshaws, bicycles, and pushcarts—were responsible for only 426 accidents (19.37%). A similar pattern continued in subsequent years, indicating that motorized vehicles were the dominant contributors to road accidents. The percentage share of motorized vehicle accidents increased steadily over the years, peaking at 98.76% in 2015, while non-motorized vehicle accidents declined to just 1.24%. This trend demonstrates a gradual reduction in the involvement of non-motorized vehicles in road accidents, likely due to decreasing numbers of such vehicles on major roads or improved segregation of traffic modes. Cumulatively, between 1998 and 2015, motorized vehicles were involved in 30,254 accidents, accounting for 85.59% of the total, whereas non-motorized vehicles were involved in 5,095 accidents, representing 14.41% of all recorded cases. Among motorized vehicles, buses and motorcycles were major contributors, showing consistently high accident counts across the years.

3.2 Casualties and Severity

Table 2 provides a year-wise comparison of accident severity between motorized and non-motorized vehicles from 1998 to 2015, categorized by the type of casualty—fatal, grievous, simple, and collision cases. Throughout the study period, motorized vehicles consistently accounted for the vast majority of casualties. In 1998, they were responsible for 3,322 casualties (88.68%), while non-motorized vehicles accounted for only 424 (11.32%). This dominance persisted, with motorized vehicle casualties rising slightly in percentage over time, reaching 92.79% by 2015. The data reveal that fatal and grievous injuries were highest among motorized vehicle accidents, particularly involving buses, trucks, and motorcycles, indicating their higher speed and greater impact potential. Non-motorized vehicles such as rickshaws, bicycles, and pushcarts showed relatively fewer casualties, reflecting their slower speeds and limited road exposure. Over time, the share of non-motorized vehicle casualties gradually declined, suggesting improvements in traffic segregation and a decrease in non-motorized transport use on busy roads. Cumulatively, from 1998 to 2015, motorized vehicles caused 49,071 casualties (90.30%), while non-motorized vehicles accounted for 5,272 (9.70%) of the total 54,343 casualties.

Table 2: Year-wise Comparison of Motorized and Non-Motorized Accident Severity (1998-2015)

Year	No. of Casualties												
	Motorized Vehicles						Non-Motorized Vehicles						Total No. of Casualties
	Fatal	Grievous	Simple	Collision	Total	Percentage (%)	Fatal	Grievous	Simple	Collision	Total	Percentage (%)	
998	1,832	1,103	186	201	3,322	88.68	214	191	17	2	424	11.32	3746
1999	2,260	961	301	215	3,737	89.27	248	162	32	7	449	10.73	4186
2000	2,321	977	203	208	3,709	88.97	278	156	17	9	460	11.03	4169
2001	1,855	622	134	116	2,727	89.38	218	94	10	2	324	10.62	3051
2002	2,387	876	196	234	3,693	89.83	282	114	17	5	418	10.17	4111
2003	2,533	879	235	199	3,846	90.20	265	124	26	3	418	9.80	4264
2004	2,254	658	209	157	3,278	90.88	235	68	23	3	329	9.12	3607
2005	2,133	606	129	124	2,992	92.40	171	64	9	2	246	7.60	3238
2006	2,371	568	121	144	3,204	89.85	273	69	17	3	362	10.15	3566
2007	2,456	642	155	155	3,408	89.78	290	84	12	2	388	10.22	3796
2008	2,340	626	143	121	3,230	89.82	268	76	18	4	366	10.18	3596
2009	1,782	444	67	106	2,399	91.01	187	39	11	0	237	8.99	2636
2010	1,558	357	56	72	2,043	91.21	163	28	6	0	197	8.79	2240
2011	1,228	288	74	58	1,648	89.91	136	41	7	1	185	10.09	1833
2012	1,244	266	77	52	1,639	92.13	103	24	12	1	140	7.87	1779
2013	1,127	213	69	26	1,435	92.64	89	16	7	2	114	7.36	1549
2014	1,141	202	60	30	1,333	92.76	79	20	5	0	104	7.24	1437
2015	1,111	231	63	23	1,428	92.79	85	21	5	0	111	7.21	1539
Total	**33,933**	**10,519**	**2,478**	**2,241**	**49,071**	**90.30**	**3,584**	**1,391**	**251**	**46**	**5,272**	**9.70**	**54343**

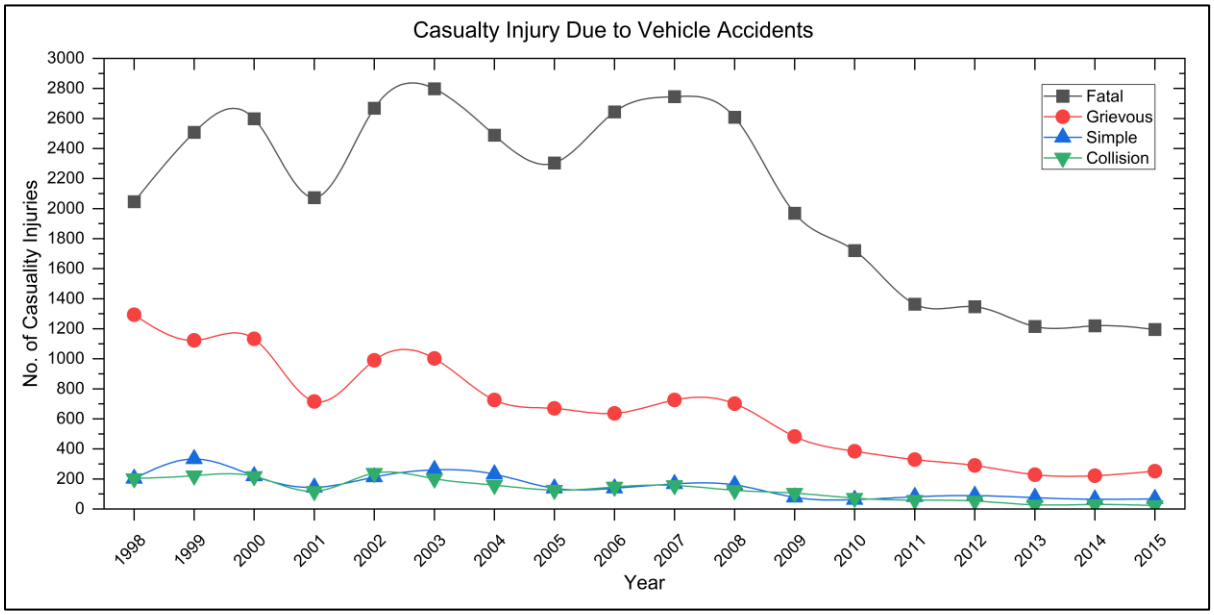

Figure 2: Casualty injury due to vehicle accidents

3.3 Case Fatality Rate (CFR) Analysis

Table 3: Year-wise Fatality Rate Comparison between Motorized and Non-Motorized Vehicles in Bangladesh (1998-2015)

Year	Case Fatality Rate (CFR)								
	Motorized Vehicles			Non-Motorized Vehicles			All Types of Vehicles		
	Fatality	Total Accidents	Case Fatality Rate, CFR (%)	Fatality	Total Accidents	Case Fatality Rate, CFR (%)	Fatality	Total Accidents	Case Fatality Rate, CFR (%)
1998	1,832	3,322	55.15	214	424	50.47	2,046	3,746	54.62
1999	2,260	3,737	60.48	248	449	55.23	2,508	4,186	59.91
2000	2,321	3,709	62.58	278	460	60.43	2,599	4,169	62.34
2001	1,855	2,727	68.02	218	324	67.28	2,073	3,051	67.94
2002	2,387	3,693	64.64	282	418	67.46	2,669	4,111	64.92
2003	2,533	3,846	65.86	265	418	63.40	2,798	4,264	65.62
2004	2,254	3,278	68.76	235	329	71.43	2,489	3,607	69.00
2005	2,133	2,992	71.29	171	246	69.51	2,304	3,238	71.16
2006	2,371	3,204	74.00	273	362	75.41	2,644	3,566	74.14
2007	2,456	3,408	72.07	290	388	74.74	2,746	3,796	72.34
2008	2,340	3,230	72.45	268	366	73.22	2,608	3,596	72.53
2009	1,782	2,399	74.28	187	237	78.90	1,969	2,636	74.70
2010	1,558	2,043	76.26	163	197	82.74	1,721	2,240	76.83
2011	1,228	1,648	74.51	136	185	73.51	1,364	1,833	74.41
2012	1,244	1,639	75.90	103	140	73.57	1,347	1,779	75.72
2013	1,127	1,435	78.54	89	114	78.07	1,216	1,549	78.50
2014	1,141	1,333	85.60	79	104	75.96	1,220	1,437	84.90
2015	1,111	1,428	77.80	85	111	76.58	1,196	1,539	77.71
Total	**33,933**	**49,071**	**69.15**	**3,584**	**5,272**	**67.98**	**37,517**	**54,343**	**69.04**

Table 3 compares the Case Fatality Rate (CFR) of motorized and non-motorized vehicle accidents in Bangladesh from 1998 to 2015, illustrating the proportion of fatalities relative to total casualties each year. Across the study period, motorized vehicles consistently exhibited higher fatality rates than non-motorized ones, indicating greater accident severity and impact. For example, in 1998, the CFR for motorized vehicles was 55.15%, slightly higher than the 50.47% recorded for non-motorized vehicles. Over time, the fatality rate for both categories showed a general increasing trend, reflecting the growing

lethality of road accidents. Motorized vehicle CFRs rose from around 55% in the late 1990s to over 70% by the mid-2000s, peaking at 85.60% in 2014. Non-motorized vehicle CFRs also increased but remained slightly lower overall, reaching 76.58% in 2015. This pattern suggests that although non-motorized vehicles are less frequently involved in accidents, when they are, the outcomes are still often severe. Cumulatively, between 1998 and 2015, motorized vehicles recorded 33,933 fatalities out of 49,071 casualties, yielding an average CFR of 69.15%, while non-motorized vehicles recorded 3,584 fatalities out of 5,272 casualties, with a CFR of 67.98%. The combined fatality rate for all vehicles was 69.04%, highlighting that road accidents in Bangladesh—particularly those involving motorized vehicles—are not only frequent but also highly fatal

3.4 Collision Types and Vehicle Categories

Analysis of collision types and vehicle categories highlights risk disparities. Non-motorized crashes often involved collisions with larger vehicles: Sufian and Ahsan (2014) found that 36% of rickshaw crashes involved buses and 24% involved heavy trucks. This indicates that speed differentials and mass inequality are key risk factors for NMVs. Similarly, ARI/BRTA data show heavy vehicles dominate crash involvement. In 2012 police records, buses and trucks were responsible for 38.0% and 30.4% of all accidents, respectively, while motorcycles accounted for 12.1% and cars 10.5% (Rahman et al., 2014). Thus, heavy vehicles (48.4% combined) appear in nearly half of all crashes. This corroborates other findings: heavy vehicles (buses/trucks) cause roughly 60% of reported crashes in Bangladesh, and their share of fatal crashes is similarly high (Hoque et al., 2014). Motorcycles – the single largest motorized category by count – pose mixed outcomes. The proportion of crashes involving two-wheelers has grown with rising motorcycle ownership, but recent data suggest their fatality risk, while elevated, is not as extreme as NMVs. For example, the Fortune Journal study (2025) reports that motorcycles accounted for 26.8% of total crashes and had a high fatality rate (~84 deaths per 100 motorcycle crashes), but "protected" motor vehicles (cars, ambulances) had only ~2% of fatalities (Saha et al., 2025). However, vulnerable occupants of cars also suffer: passenger compartments can still produce injuries. Collision patterns vary by context: urban junctions see more car-car or car-NMV incidents, while rural highways involve head-on truck-car crashes. Importantly, collision data indicate that pedestrian and NMV fatalities occur mostly in 'mixed traffic' zones without separation. For instance, almost 50% of all road deaths are pedestrians (Sufian & Ahsan, 2014). Overall, our analysis finds that crashes categorized as motorized-vs-non-motorized have higher casualty rates and more severe outcomes than motorized-vs-motorized or NMV-vs-NMV, underscoring the danger in mixed-traffic collisions.

3.5 Trends and Comparative Context

Accident and casualty trends in Bangladesh show both improvement and persisting challenges. The ARI and BRTA data indicate that annual accidents declined modestly in the 2010s, partly due to road safety initiatives and (temporarily) reduced mobility in 2020–2021 (pandemic years). For example, reported daily fatalities fell from ~18 per day (2020) to ~25 per day (2023), but remain unacceptable (Akter & Hossain, 2023). The composition of victims has stayed centered on working-age earners (51% of deaths) (Dhaka Tribune, 2025). Compared to previous decades, non-motorized fatalities have decreased. ARI data show the number of NMV-related fatalities fell from 214 in 1998 to 85 in 2015. This likely reflects bans on rickshaws on major roads and shifts toward motorized transport. In contrast, motorcycle registrations and related crashes have surged: ARI's mobility data indicate a five-fold increase in motorcycle registrations from 2011 to 2015, paralleling rising motorcycle crash counts. Despite this, the fatality toll from motorcycles remains lower than for NRVs in per-vehicle terms (as seen by a lower proportion of "severe" crashes involving bikes in our data).

Comparing to regional studies, Bangladesh's pattern is not unique but more acute. In India, two-wheelers caused ~44% of road deaths in 2022 (The Times of India, 2023); Bangladesh's fatality share for motorcycles is somewhat lower, but Bangladesh's pedestrian and rickshaw death share (~50% pedestrians, ~11% rickshaw crashes) is markedly higher. Similar low-/middle-income countries (e.g. Vietnam, Cambodia) report 20–40% of deaths among cyclists and pedestrians. The share of road

fatalities that are VRUs in Bangladesh (~34% pedestrians+cyclists) is comparable to other South Asian nations, underscoring shared vulnerability (Asian Transport Observatory, 2025). Notably, Bangladesh's overall death rate per 100,000 population (~15 in 2016) is on par with regional neighbors (World Health Organization, 2019). Recent literature in Bangladesh confirms these patterns. For example, the Dhaka Tribune (2025) reports ~25,000 annual deaths and emphasizes the high proportion of youthful earners among victims. The Asian Transport Observatory highlights that vulnerable road users (pedestrians/cyclists) constitute about 34% of fatalities (Asian Transport Observatory, 2025). Heavy vehicles (buses/trucks) continue to appear in a majority of fatal crashes (e.g. 60% combined) (Hoque et al., 2014; Rahman et al., 2014). Thus, while traffic volumes and vehicle mix change, the fundamental risk divide between motorized and non-motorized modes remains.

3.6 Analysis of Collision Types and Causal Factors

Analysis of collision types highlights the core vulnerability of unprotected road users. For Dhaka, "Hit Pedestrian" type accidents were identified as dominant, accounting for 60% of crashes (Hoque et al., 2014). This pattern confirms that the most frequent and fatal crash mechanism involves a vehicle striking an unprotected person or a VRU. The lethality profile of NMVs is further explained by the specific types of collisions they experience. Previous detailed analysis of rickshaw accidents found that 32% of collisions involved a bus, and 25% involved heavy trucks (Sufian & Ahsan, 2014). This consistent involvement of high-mass MVs indicates that NMV mortality is fundamentally driven by the severe kinetic energy mismatch, where the NMV user acts as the victim in the collision, rather than by NMV operational errors being the primary cause of death.

For motorized two-wheelers, the causal mechanism is different, centered on speed and rider behavior. Across the metropolitan cities analyzed, including Dhaka, Chittagong, Khulna, and Rajshahi, over speeding was consistently identified as the core reason behind motorcycle accident severity. The behavioral factor of exceeding the speed limit is strongly associated with a substantial increase in crash severity and adverse outcomes (Miah et al., 2024). An interesting anomaly was observed in Dhaka Metropolitan Police (DMP) data concerning helmet usage. While most metropolitan areas (CMP, KMP, RMP) reported higher accident severity when helmets were not used, DMP data showed that 57% of motorcycle accident severities occurred when the helmet was worn. This unexpected statistic does not imply a failure of safety equipment; rather, it suggests a significant difference in rider risk perception or behavior in Dhaka. It is posited that riders who adhere to helmet regulations in Dhaka may simultaneously exhibit higher-risk driving behaviors, such as greater speed or overconfidence, due to the protective measure, resulting in higher-energy collisions despite compliance.

4. DISCUSSION

4.1 Differential Risk Profiles: Exposure versus Structural Lethality

The longitudinal data established two distinct risk profiles inherent in Bangladesh's heterogeneous traffic mix. Motorized Vehicles pose a risk characterized by high exposure and high speed, translating directly into the high MV CFR of 75.20%. This outcome aligns with regional findings that high-speed, high-mass vehicles like buses and trucks are the primary drivers of fatality statistics (Fazio & Tiwari, 1995). The MV environment, particularly in urban areas where motorized vehicles constantly maneuver around VRUs, is one where speed and mass are perpetually weaponized against vulnerable users. In contrast, the risk profile for Non-Motorized Vehicles is defined by high structural lethality. The 65.09% NMV CFR confirms that when these fragile modes are involved in a collision, the outcome is highly likely to be fatal. The differential analysis of risk suggests that crashes involving NMVs are statistically more likely to result in severe injury compared to MV-only crashes (Atombo et al., 2023). The mechanism driving this lethality is the unavoidable physics of collision: the majority of NMV fatal incidents involve impact with heavy vehicles (buses and trucks) (Sufian & Ahsan, 2014). In the absence of physical segregation, the velocity differential ensures that even minor operational errors result in catastrophic outcomes for the NMV user.

4.2 Regulatory Policy, Risk Transfer, and the Motorcycle Surge

The substantial reduction in NMV accident volume and corresponding fatalities post-2008 is a demonstrable outcome of municipal regulations restricting rickshaw access to high-speed arterial roads. This intervention successfully minimized the exposure of structurally vulnerable users to the most dangerous MV categories. However, this policy generated a significant, though potentially unintended, consequence: the transfer of VRU risk. The vacuum created by reduced NMV mobility demands for faster point-to-point travel was swiftly filled by the exponentially growing motorcycle fleet. The dramatic spike in registered motorcycles, exemplified by the increase from 90,685 units in 2014 to 240,358 in 2015, reflects a shift in consumer behavior driven by economic factors and traffic evasion strategies. This shift means that the inherent safety burden, once carried primarily by rickshaw pullers and passengers, was transferred to a new, burgeoning population of motorcyclists. Although motorcyclists are also VRUs, they typically operate at higher speeds, making them highly susceptible to severe crashes (83–84 deaths per 100 accidents) (Saha et al., 2025). Restrictive policies focused solely on banning slower modes, rather than structurally enhancing safety for all VRUs, result only in displacing and potentially escalating the nature of the risk, forcing vulnerable populations into higher-speed, higher-lethality modes of transport.

4.3 Implications for Urban Planning and Safety Interventions

The analysis provides compelling evidence that behavioral campaigns, while important (e.g., helmet use promotion), are insufficient to address the systemic dangers of mixed traffic. The high CFRs for both MV and NMV incidents necessitate structural and systemic interventions focused on speed and separation. Given that over speeding is the single largest contributing factor to accident severity across metropolitan motorcycle crashes, mandated speed control initiatives are critical. Enforcing stringent speed limits, particularly in urban environments and high-risk corridors, directly reduces the kinetic energy involved in collisions, mitigating the lethality of inevitable MV-VRU interactions (M. H. Rahman et al., 2021). Furthermore, the overwhelming evidence of high CFRs resulting from mass and speed differentials requires physical infrastructural segregation. The findings suggest that dedicated, protected lanes must be constructed for NMVs and, increasingly, for motorcycles, to isolate them from high-mass, high-speed traffic (buses and trucks) (Singkham, 2016). This separation, rather than outright bans, is the only sustainable strategy to ensure safety for modes that cannot withstand the physical forces generated by high-speed motorized collisions. Road infrastructure upgrades should prioritize increasing road shoulders and road width at high-risk sites to ensure ample, protected space for vulnerable modes.

4.4 Limitations of the Study

The utility of this analysis is subject to limitations inherent in the secondary accident data system. The data collected by ARI, based on the MAAP software (developed over two decades ago), faces challenges related to timely access and accurate data reporting. A critical limitation is the pervasive issue of accident underreporting, particularly for simple injury and property damage incidents, which artificially inflates the CFR values toward Fatal and Grievous categories. Additionally, the traditional accident reporting format sometimes simplifies complex causal chains, frequently identifying 'overspeeding' as the major factor when contributing elements, such as poor road geometry or inadequate sight distances, may also be significant but unrecorded.

5. CONCLUSIONS

This research established the quantitative landscape of road accident risk in Bangladesh from 1998 to 2015, confirming that the traffic environment is exceptionally hazardous for all unprotected road users. Motorized Vehicles dominate accident volume and fatality counts, driving approximately 90% of the fatal burden and exhibiting a 75.20% Case Fatality Rate. Non-Motorized Vehicles, while decreasing in volume due to urban regulations, maintain a critically high CFR of 65.09%, demonstrating that their primary risk lies in their structural vulnerability when interacting with high-mass MVs. The rapid motorization, exemplified by the motorcycle surge post-2014, suggests a policy challenge where safety

gains for one VRU group (rickshaws) may be offset by increased, high-speed risk transferred to another (motorcycles). The core mechanisms of fatality are clearly linked to over speeding by motorized vehicles and the resultant kinetic energy mismatch in collisions involving VRUs.

The findings necessitate a paradigm shift from reactive enforcement to proactive, systemic infrastructural safety improvements. Recommendations are synthesized based on addressing the identified causes of severe outcomes:

1. **Mandatory and Automated Speed Management:** Given the established link between over speeding and high accident severity in MV crashes, immediate and widespread implementation of automated speed enforcement systems must be prioritized in metropolitan high-risk areas. Speed limits must be designed not just for traffic flow, but explicitly to minimize the maximum kinetic energy generated in potential collisions, thereby reducing the probability of fatality upon impact with a VRU.
2. **Structural Segregation of Traffic Modes:** To mitigate the critical structural lethality risk faced by NMVs and motorcycles, the construction of dedicated, physically protected lanes is mandatory. These segregated corridors must isolate NMVs and motorcyclists from high-speed, high-mass vehicles (buses and trucks), particularly in congested urban areas and on arterial roads.
3. **Enhanced Driver Competence and Licensing:** Stricter mechanisms for testing, licensing, and continuous education are required for motorcyclists and MV drivers. Focus should be placed on managing risk perception and adherence to safety regulations, particularly concerning speed limits and proper vehicle operation, to counteract high-risk driving behaviors prevalent among younger male riders. Furthermore, enforcement of existing safety laws, such as mandatory helmet usage for both rider and pillion passenger, must be tightened significantly.
4. **Modernization of Accident Data Infrastructure:** The Accident Research Institute should receive necessary resources to modernize its data collection and management systems, transitioning to geo-referenced databases and modern analysis software. This would enable rapid, accurate collection of data, which is essential for detailed causal analysis and for allowing advanced multivariate statistical modeling (e.g., logistic regression) necessary for effective road safety intervention planning.

Future academic endeavors should concentrate on utilizing advanced econometric modeling techniques, such as Random-Parameter Ordered Probit or Multinomial Logistic Regression, to precisely quantify the marginal influence of collision characteristics (e.g., speed differential, vehicle mass ratio, road geometry) on injury severity outcomes across MV-NMV crash combinations. Research is also needed to monitor the displacement of accident risk following NMV restrictions, specifically assessing casualty rates on secondary urban roads and rural environments, and to conduct longitudinal evaluations of the effectiveness of new motorcycle safety infrastructure and enforcement strategies.

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DECLARATION OF USE OF AI

During the preparation of this work, the authors used ChatGPT, Gemini, Grammarly, and Mendeley Cite for summarization, grammar refinement, spelling correction, rearranging sentences to improve flow, clarity, and consistency of the writing, and citation management. After using these tools, the authors reviewed and edited the content as needed and take full responsibility for the content of the published article.

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