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Evaluation of Factors Affecting Severity of Motorcycle Crash at Intersections in Kathmandu Valley

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Abstract

Motorcyclists face a heightened risk of fatal and serious injuries due to their inherent lack of protection compared to occupants of other vehicles. Intersection-related accidents, in particular, have been shown to result in more severe outcomes. This research endeavors to investigate the determinants of motorcycle crash severity at intersections. Using a multinomial logit model, the analysis explores a range of contributing factors, classifying crash severity into three distinct categories: minor injury, serious injury, and fatal injury. This study aims to shed light on crucial aspects of motorcycle safety at intersections, offering valuable insights into the factors that influence the outcomes of these often-perilous incidents.This research paper presents the results of a Multinomial Logit (MNL) estimation, aiming to understand the factors influencing the severity of motorcycle crashes at intersections in Kathmandu. The study focuses on two severity categories: "Minor" and "Serious" with the base category being "Fatal Injury". The analysis includes coefficient estimates, significance levels, and Relative Risk Ratios (RRR) for all variables considered in the MNL model.Among the variables analyzed, the time at which the crash occurred emerged as a significant factor at a 95% confidence level. Collisions with trucks are found to be 11 times more likely to lead to fatal injuries compared to minor injuries and 9 times more likely than serious injuries. Collisions with roadside objects are 12 times more likely to result in fatal injuries compared to minor injuries and 5 times more likely than serious injuries. Early morning accidents have a three-fold higher risk of causing fatal injuries than minor injuries and five times higher risk than serious injuries. Conversely, accidents during non-rush hours show a reduced risk of fatal injuries compared to minor injuries but are three times more likely to result in fatal injuries than in cases involving serious injuries. These insights have significant implications for motorcycle safety and targeted interventions.

Keywords

Multinomial Logit Model, Injury Severity, Motorcycle Crashes, Intersection, Risk Factors

1. Introduction

Traffic safety is a big worry all over the world, and it's an even bigger problem in places that are still developing. The issues in these areas are more serious for some straightforward reasons: they don't do enough to make sure people on the roads, whether they're driving, biking, taking buses, or just walking, are safe.

Motorcycle riders, due to their limited protective gear, face a higher likelihood of encountering severe and even fatal injuries for every mile they travel, in contrast to drivers of other vehicles who enjoy more substantial safety measures [1]. Annually, a staggering 1.2 million lives are tragically lost in traffic accidents, with nearly half of this grim statistic being made up of vulnerable road users, including motorcyclists, bicyclists, and pedestrians [2]. This report on global road safety further reveals that motorcyclists, accounting for approximately one-fourth of these yearly road fatalities, face a particularly substantial risk on the world's roads [3]. Over the course of the decade spanning from 2006 to 2016, a significant shift was observed in the realm of road-related fatalities. The number of recorded fatalities, previously hovering around 1,000, underwent a substantial transformation, surpassing the 2,000 mark. This transformation represents a noteworthy doubling of registered road-related fatalities during the specified time frame. [3].

Nonetheless, when accounting for the potential of under-reporting, the World Health Organization (WHO) contends that the genuine count of road-related fatalities may be notably greater. Their estimations suggest a range extending from 3,880 to 5,546 traffic-related deaths, highlighting the potential for a substantial under-representation of the true toll of road accidents [3]. In the latest data reported by the Nepalese Police Force for the year 2021/22, there were a total of 9,697 road-related injuries recorded within the Kathmandu Valley. Among these incidents, 159 tragically resulted in fatal crashes (Nepal Police, 2022). Nepal is experiencing a concerning rise in road-related fatalities. These accidents are not only claiming lives but are also a major reason for increased hospital admissions due to injuries [4, 5].

Intersections serve as frequent hotspots for traffic accidents, and what makes matters worse is that collisions at these junctions tend to be more severe in nature. [6].Motorcycle accidents at intersections are unique and tend to be more serious than accidents involving other vehicles. This happens because certain dangerous types of crashes, like angle collisions, happen more often at intersections.[7]. Additionally, when motorcycles and other vehicles interact at intersections, the potential for more serious injuries to motorcyclists goes up because of the complicated way they all move around.

While motorcycle crashes may not occur more frequently than other types of accidents, they often lead to severe injuries or fatalities. Riding a motorcycle undoubtedly offers an exhilarating experience, but this excitement also comes with inherent risks. Motorcycles lack the protective features found in other vehicles, such as seat-belts and structural enclosures, making riders more vulnerable. Additionally, motorcycles' smaller size makes them less conspicuous on the road. As a result, motorcycle riding poses a considerable risk to personal safety. Recent statistics indicate a growing popularity of motorcycles in Kathmandu, with more people opting for this mode of transportation than ever before.

Another problem is that vehicles commonly used at these locations are often old and not well-maintained, which increases the risk of accidents. Moreover, the rising number of people using motorcycles and bicycles without proper safety gear adds to the danger.

People who travel in cars and buses face risks as well, especially in developing countries where the safety of these vehicles may be lacking. Accidents can lead to numerous injuries and even fatalities. Additionally, crowded and poorly maintained buses and trains further increase the risk for passengers.

Even pedestrians encounter difficulties in developing countries. They often lack proper walking paths, such as sidewalks, and crossing the road safely can be challenging because drivers may not always give them the right of way.

2. Methodology

2.1 Research Design

Figure 1 shows the flowchart of the research framework. It summarizes the methodological framework used in this study for the use of MNL model. Two types of crash data were collected: motorcyclist and crash characteristic type data. For analysis IBM SPSS was used.

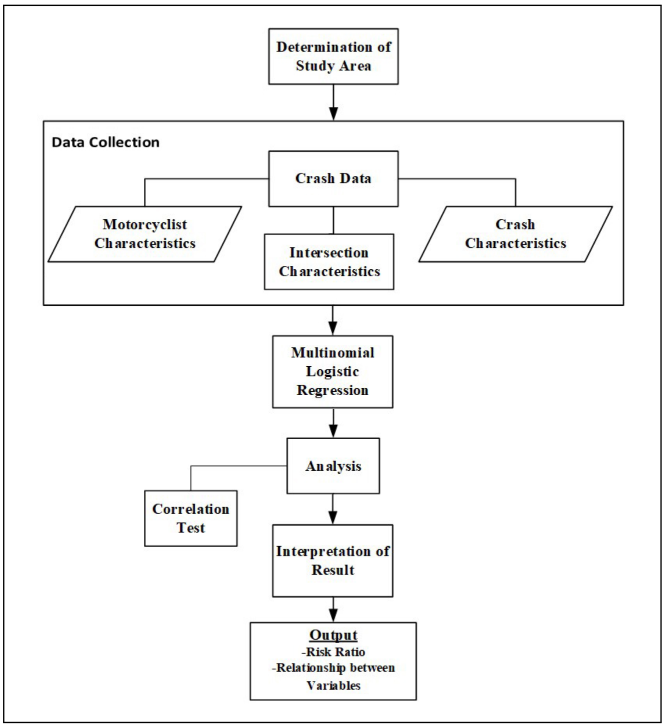

Figure 1: Methodology

2.1.1 Data Collection

The study is founded upon secondary data sources. For developing the model, the motorcycle crash data recorded at Kathmandu Valley Traffic Police Office from the fiscal year 2074-075 to 2078-079 B.S. (2017/018 to 2021/022 A.D.) were used.

A dataset consisting of 3,086 motorcycle accidents near intersections was analyzed after merging and eliminating incomplete records. Any accident that occurred within a 10-meter distance from an intersection was classified as an "intersection crash."

2.1.2 Data Extraction

Bike accidents were initially segregated from the comprehensive dataset. Among these, incidents occurring at intersections were isolated. All identifiable intersections were subsequently selected and processed in preparation for further analysis.

2.2 Study Area

In pursuit of research objectives, the acquisition of motorcycle crash data arising at intersections within the Kathmandu Valley constitutes a fundamental prerequisite. This study has identified and subsequently designated 286 intersections within the Kathmandu Valley as the focal points for analytical investigation. These intersections have been selected on the criterion that they have experienced at least one recorded motorcycle accident. Figure 2 shows the locations of these intersections along with its types.

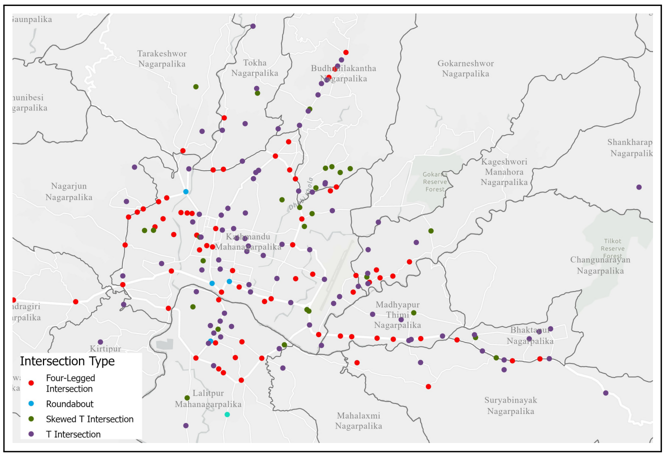

Figure 2: Locations of Intersections within Kathmandu Valley

2.3 Risk Factors

The study presents a multinomial logit model which will identify the significant risk factors that associates to motorcycle crash severity at intersections of Kathmandu and also will quantify the variation in the severity the factors can bring into. For this, based on the literature review and a pilot review of the crash statistics of Kathmandu, a list four potential risk factors are considered. The factors can be classified into three broad categories as discussed below.

2.3.1 Motorcyclist Characteristics

Age and gender were taken into account as potential risk factors that could influence the severity of motorcycle accidents at intersections. Previous research has shown multiple methods for categorizing motorcyclists based on their age [8, 9]. To accommodate the varying riding styles across age groups, a widely used classification method was adopted, wherein motorcyclists are categorized into three age groups: young (under 26 years), middle-aged (26–59 years), and older motorcyclists (60 years and above).

Driving under the influence (DUI) and overspeeding are two significant factors that contribute to road crashes worldwide. These behaviors significantly increase the risk of accidents, injuries, and fatalities on the roads [10].

2.3.2 Crash Characteristics

The study also encompassed an analysis of both the day of the week and the time of motorcycle crashes. The classification of days of the week followed the prevailing norm, delineating them into "weekday" and "weekend" categories.

Drawing upon prior literature, the time of the crash was further segmented into five distinct intervals contingent upon traffic volume[9]: "mid-night/early morning" (00:00–6:29 a.m.), "morning rush hours" (6:30–8:59 a.m.), "non-rush hours" (9:00 a.m. to 14:59 p.m.), "evening rush hours" (15:00–18:29 p.m.), and "evening" (18:30–23:59 p.m.).

Furthermore, motorcycle crashes were categorized into four distinct types, namely: "collision with a vehicle," "collision with a pedestrian," "collision with a roadside object," and "loss of control" (no collision). Moreover, an additional three categories have been incorporated, encompassing "collision with a truck," "over-speeding," and "driving under the influence."

2.3.3 Intersection Characteristics

The intersections under consideration in this study were categorized into four distinct groups, namely: four-legged intersections, T-type intersections, skewed T-type intersections and roundabout.

2.4 Data Analysis

For this study, the SPSS (Statistical Package for the Social Sciences) software was utilized for performing multiple regression analysis. Multiple regression analysis is a statistical method employed to investigate and model connections between a dependent variable (the outcome of interest) and several independent variables (factors believed to impact the dependent variable).

2.4.1 Model Formulation

This study introduces a comprehensive crash severity model, using the Multinomial Logit Model (MNL) as the tool for analysis. The aim is to understand how motorcycle accidents unfold and how they relate to different risk factors. The severity of accidents were divided into three categories: minor injuries (which need medical attention, like bruises or pain), serious injuries (leading to hospitalization), and fatal injuries (resulting in death within 30 days). Accidents that only involve property damage were intentionally excluded and focused on those where people are injured. This is because data on property-only accidents can be unreliable and often go unreported.

An unordered model, such as the multinomial logit model, has been recommended for use in crash severity studies, even though crash severity inherently follows a natural order [8, 11].The investigations revealed that when it comes to underreporting in the data, the multinomial logit model is less affected [12], given that the dataset being studied exhibits the quality of independence of irrelevant alternatives, (IIAs) [13].Additionally, this model offers a more adaptable and versatile functional approach [14].

The MNL model that will be used in this study is presented below in equation 1 [15]:

$$P_{ni} = \frac{e^{\beta_i X_{ni}}}{\sum_{i=1}^{I} e^{\beta_i X_{ni}}}, \quad i = 1, 2, \ldots, I \tag{1}$$

Where,
P_{ni}: Probability of the motorcyclist in the crash n to suffer the output injury of i,
β_i: A vector of the calculative coefficient for the output severity I associated with X_n,
X_n: Vector of the explanatory variables.
The coefficients for the reference category are set to zero in this study, with fatal injury crashes serving as the reference category. While the choice of using fatalities as the baseline for calculating probabilities and relative risks may impact the robustness of the analysis, especially when fatalities are infrequent, recent research has recommended that fatal crashes should consistently be designated as the reference category for the Multinomial Logit Model (MNL). This practice is suggested to minimize bias and reduce variability in the model [8, 11, 16]. Additionally, it's worth mentioning that fatal injuries tend to be reported more consistently.
Due to the nonlinear attributes inherent in the multinomial logit model, the estimated coefficients associated with independent variables are incapable of directly signifying their impact on the dependent variable.

To address this limitation, this study has leveraged the Relative Risk Ratio (RRR) parameter for the purpose of risk assessment. It is noteworthy that the RRR parameter takes into account not only the influence of individual independent variables but also considers the collective effects of various factors. These encompass motorcyclist characteristics, environmental attributes, intersection properties, and crash-related variables, in addition to accounting for the interrelationships and covariances among these independent variables.
The Relative Risk Ratio (RRR) parameter associated with each independent variable serves as an indicator of the risk pertaining to a specific crash severity in relation to the reference category. Specifically, when RRR > 1, it signifies an escalation in the risk, while RRR < 1 indicates a reduction in the risk [15].

In this research, both the Multinomial Logit Model (MNL) and the RRR are estimated with a confidence level of 95% and subjected to analysis using IBM SPSS software.

Table 1: Summary of Motorcycle Crash Data

Variables	Type	N
Severity Level	Fatal	51
	Minor	2948
	Serious	87
Weekday	Weekday	2652
	Weekend	434
Intersection type	Four-legged	1905
	T-type	890
	Skewed T-type	225
	Roundabout	66
Over-speeding		337
Driving Under Influence		
Collision with Truck		208
Gender	Male	2607
	Female	479
Collision	Collision with vehicle	2467
	Collision with pedestrian	339
	Collision with roadside object	40
	No collision (loss of control)	240
Age Group	Young	1388
	Middle-aged	1677
	Old	21
Time Group	Early Morning	143
	Morning Rush	260
	Non-Rush	1135
	Evening Rush	762
	Evening	786
Total		3086

2.4.2 Correlation Test

In the context of Multinomial Logistic Regression, the chi-square test and Cramer's V are valuable tools for assessing the correlation between categorical variables. These statistical tests play a crucial role in understanding the relationships among different factors and can help identify significant associations within the dataset.

The chi-square test is commonly employed to examine the independence of categorical variables by comparing observed frequencies with expected frequencies. In the context of multinomial logistic regression, the chi-square test serves as an initial step to determine whether there is a significant correlation between predictor variables. A low p-value from the chi-square test suggests that there is evidence of association, prompting further investigation into the specific nature and strength of these associations.

Following the chi-square test, Cramer's V becomes instrumental in gauging the strength of the identified correlations. Cramer's V is a measure of association between categorical variables, ranging from 0 (no association) to 1 (complete association). In the realm of multinomial logistic regression, Cramer's V provides insights into the degree of correlation among predictor variables. It is particularly useful in quantifying the strength of associations when dealing with nominal or ordinal variables.

3. Result and Discussion

3.1 Overview of Motorcycle Crashes at Intersections in Kathmandu Valley

The crash data recorded from the Traffic police are summarized in Table 1. The "Summary of Motorcycle Crash Data" table concisely encapsulates the key insights from motorcycle accident records. It classifies accidents into different severity levels, with minor incidents being the most prevalent, followed by serious and fatal cases. The data is further broken down by variables such as the day of the week (weekdays and weekends), types of intersections, factors like over-speeding and driving under the influence, the gender of those involved, collision types, age groups, and the time of day when accidents occurred. Notably, the largest number of accidents is associated with "Non-Rush" times. With a total of 3,086 recorded accidents, this dataset serves as a valuable resource for comprehending accident patterns and contributing factors, facilitating informed decision-making in the realm of road safety and accident prevention.

3.2 Results of Correlation Analysis

The results of the chi-square tests and the corresponding Cramer's V values for categorical variables are presented in Table 3. The p-values from the chi-square tests assessing the correlation between Age and Collision with Truck, Gender and Time, Gender and DUI, Time and Over-speeding, Time and Intersection Type, DUI and Intersection Type, and Intersection Type and Collision Type are all less than or equal to 0.05. As a result, these pairs are deemed statistically significant. However, upon examining the Cramer's V values for these significant pairs, it was observed that the relationships between them are weak. Nevertheless, all categorical variables were included in the subsequent analysis, recognizing the weak relationships (less than 0.3) indicated by the Cramer's V values for the significant pairs.

3.3 Relative Risk Ratios for the Identified Risk Factors

Table 2 presents the results of the MNL estimation. The tables include the coefficient estimates, significance, and RRR($e\beta$) for all the variables for severity categories minor severity and serious severity respectively. The base category for the corresponding model is fatal injury, the coefficient estimates explain the differences compared to the fatal injury. The variables that are significant at the 95% confidence level are identified. The significant factors that influence the injury severity of motorcycle crashes at a 95% confidence level was time at which the crash occurred.

In order to analyze the table and delve into the relative risk ratio (RRR) of noteworthy variables, it is crucial to pinpoint the variables that achieve statistical significance, often characterized by a p-value (Sig.) below a predetermined significance threshold, such as 0.05.

The analysis provides compelling insights into the disparities in injury severity outcomes resulting from collisions involving trucks, along with their Relative Risk Ratios (RRR). The data shows that when a collision involves a truck, the likelihood of a fatal injury is approximately 11 times higher (RRR=1/0.091)

Table 2: The result of the MNL model for motorcycle crashes

Variable	Estimated Coefficient[a]	P-value	RRR[b] (95% CI)
Intercept [MI]	2.493 (1.482)	0.093	-
Intercept [SI]	-0.699 (1.981)	0.724	-
Collision with truck [MI]	-2.393 (0.371)	< 0.001	0.091 (0.044, 0.189)
Collision with truck [SI]	-2.236 (0.564)	< 0.001	0.107 (0.035, 0.322)
Collision with roadside object [MI]	-3.973 (0.541)	< 0.001	0.019 (0.007, 0.054)
Collision with roadside object [SI]	-2.511 (0.744)	0.001	0.081 (0.019, 0.349)
Time of crash, early morning [MI]	-1.198 (0.436)	0.006	0.302 (0.128, 0.709)
Time of crash, early morning [SI]	-1.594 (0.608)	0.009	0.203 (0.062, 0.669)
Time of crash, non-rush hours [MI]	1.296 (0.584)	0.026	3.656 (1.164, 11.481)
Time of crash, non-rush hours [SI]	-1.131 (0.511)	0.027	0.323 (0.119, 0.879)
Number of observations: 3086			
Log-likelihood: 614.816			
Chi-square: 463.184			
McFadden Pseudo R-squared: 0.154			
P-value: 0.000			

[MI], minor injury; [SI], serious injury. The reference category is the fatal injury.
[a] Standard errors are in parentheses.
[b] Lower and upper limits at 95% confidence interval are in parentheses.

compared to cases that lead to minor injuries. This substantial RRR value underscores the significantly increased risk of severe outcomes associated with such collisions. Additionally, when contrasted with incidents that result in serious injuries, collisions with trucks are about 9 times more likely to lead to fatal injuries (RRR=1/0.107). These RRR values not only highlight the elevated risk of fatal injuries in truck-involved accidents but also underscore the importance of implementing targeted safety measures and accident prevention strategies to mitigate these risks and enhance overall road safety.

Table 3: Chi-Square and Cramer's V Value for the Categorical Variables

Variables	Chi square (p-value)	Crammer's V
Age & Collision with Truck	0.003	0.062
Gender & Time	0.01	0.065
Gender & DUI	0.002	0.056
Time & Over-speeding	0.004	0.071
Time & Intersection Type	0.016	0.052
DUI & Intersection Type	0.048	0.051
Intersection Type & Collision Type	0.005	0.051

Collisions involving roadside objects exhibit a significantly elevated likelihood of resulting in fatal injuries when compared to minor injuries, as indicated by a Relative Risk Ratio (RRR) of approximately 1/0.019. In a similar vein, these collisions are approximately 12 times more inclined to lead to fatal injuries in comparison to cases involving serious injuries, emphasizing the substantial disparity in the risk of severe outcomes associated with such accidents (RRR=1/0.081).

According to the model's findings, it appears that motorcycle accidents during the early morning hours have a significantly higher likelihood of resulting in fatal injuries when compared to minor injuries, with a Relative Risk Ratio (RRR) of approximately 1/0.302, indicating roughly three times higher risk. Similarly, these early morning accidents are about five times more prone to causing fatal injuries than cases involving serious injuries, emphasizing the substantial disparity in the risk of severe outcomes associated with accidents occurring during these hours (RRR=1/0.203).

Accidents occurring during non-rush hours exhibit a reduced likelihood of resulting in fatal injuries when compared to minor injuries, with a Relative Risk Ratio (RRR) of approximately 1/3.656, implying a lower risk. However, the data also indicates that during non-rush hours, accidents are about three times more inclined to result in fatal injuries than in cases involving serious injuries, highlighting a notable difference in the risk of severe outcomes during these time periods (RRR=1/0.323).

4. Conclusion

The examination of motorcycle accident data has provided us with valuable knowledge regarding the elements influencing the extent of injuries sustained. Importantly, certain circumstances, such as collisions with specific objects and specific time periods, have displayed unique trends. Collisions involving trucks and roadside objects are linked to a notably greater likelihood of resulting in fatal injuries when contrasted with minor and serious injuries. Accidents occurring in the early morning hours present a heightened risk of leading to fatal consequences compared to cases of minor and serious injuries. Conversely, during non-rush hours, accidents have a diminished probability of causing fatal injuries in comparison to minor injuries.

To enhance comprehension of this crucial issue, it is imperative to conduct further investigations employing diverse modeling techniques across various geographical regions. The current study had constraints related to the factors accessible in the Kathmandu traffic police accident records. Including supplementary factors, such as annual average daily traffic and road width, could facilitate a more precise and comprehensive analysis. Moreover, conducting additional research focusing on motorcycle crashes at specific types of intersections, like uncontrolled intersections, could contribute to the development of effective strategies for diminishing motorcycle accidents and associated fatalities.

The findings of this study serve as a valuable asset for both road authorities and researchers, offering essential insights for the formulation of tailored road safety initiatives and strategies aimed at mitigating the fatality rate among motorcyclists involved in intersection-related accidents.

5. Recommendation

Given the elevated risk of fatal injuries in collisions with trucks and roadside objects, it is imperative to implement comprehensive safety measures. This includes upgrading and enforcing safety features in trucks, such as collision avoidance systems, as well as improving road infrastructure to mitigate the impact of roadside collisions. Public awareness campaigns targeting safe driving behaviors around trucks and roadside objects can also be beneficial.

To address the heightened risk of fatal outcomes during early morning hours, focused safety initiatives should be put in place. This may involve increased law enforcement presence during these times, particularly on roads with high accident rates. Additionally, public education programs can promote responsible driving practices and highlight the importance of good visibility during the early morning hours.

While accidents during non-rush hours have shown a reduced likelihood of causing fatal injuries compared to minor injuries, it is still imperative to maintain road safety during these periods. Regular traffic law enforcement should continue, emphasizing the importance of adherence to speed limits and other traffic regulations, especially in areas with a history of accidents. This approach ensures that road safety is consistently upheld throughout the day.

The ongoing monitoring and analysis of motorcycle crash data is critical to staying informed about evolving trends and emerging risk factors. This data-driven approach enables timely and targeted interventions to address changing circumstances. Regular data collection and analysis can identify patterns and assess the effectiveness of safety measures over time.

Collaborative efforts between government agencies, law enforcement, and road safety organizations can foster in-depth research into motorcycle safety. This research should lead to the development of evidence-based strategies to reduce the risk of fatal injuries. Sharing knowledge, resources, and best practices among stakeholders can contribute to a safer road environment for motorcyclists and all road users.

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