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# Heavy vehicle crashes in Addis Ababa: Relationship between contributing factors and severity of outcomes

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**Abstract**: Random parameter logit regression is used to analyze police-reported data on 8,253 heavy vehicle-related crashes in Addis Ababa between July 2014 and June 2017. The analysis shows that fatal crashes are more likely to occur during the day and on weekdays, particularly when the circulation of trucks is high. It also shows the disproportionately high involvement of young drivers in heavy vehicle crashes in the city. However, the likelihood of crashes resulting in fatalities and serious injuries increases slightly compared to those resulting only in property damage as the age of drivers increases. Low levels of drivers' education, the fact that drivers are often not the owners of vehicles, ownership of vehicles by companies and government organizations, and inappropriate road medians' inappropriate design are also significant contributors to fatal crashes. Curbing deaths and injuries from heavy vehicle crashes in Addis Ababa requires strict enforcement of traffic rules and regulations, particularly speed limits; reforms in driver's training and certification; improved safety culture of vehicle owners and design of road infrastructure. Ethiopia's national road safety strategy launched in July 2022 addresses these issues. Hence the government is taking steps in the right direction.

**Keywords:** heavy vehicle, crashes, road safety, random parameter logit regression, risk, Ethiopia, Addis Ababa

## 1. Introduction

Like several African countries, Ethiopia did not meet the United Nations Decade of Action for Road Safety (2011-2020) target 3.6 of the Sustainable Development Goals to reduce crash fatalities by half by 2020. On the contrary, road traffic deaths in the country more than doubled in the 12 years between 2007 and 2018, rising from 2,161 to 4,597, according to official statistics[1] (United Nations Economic Commission for Africa and Economic Commission for Europe, 2020) (United Nations Economic Commission for Africa and Economic Commission for Europe, 2018). The country is also likely to face a

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daunting challenge to meet the target of the second United Nations Decade of Action for Road Safety (2021-2030) to reduce fatalities and injuries by half by 2030 (United Nations , 2020). Achieving this target would require evidence-based interventions. In this regard, a systematic and rigorous effort is needed to identify the categories of road users who are most at risk of death from crashes and to understand the causes of these fatal crashes. This article seeks to contribute to this effort by analysing heavy vehicle crashes that result in fatalities and injuries in Addis Ababa.

Ethiopia's economy performed remarkably from 2004 until the outbreak of the coronavirus disease 2019 (COVID-19), with the real gross domestic product (GDP) growing on average by 11 percent per year (United Nations Economic Commission for Africa and Economic Commission for Europe, 2020). That growth was reflected in a boom in the country's construction industry, notably in constructing economic and social infrastructure such as roads and buildings, particularly in Addis Ababa (Ethiopian Economic Association). The city, with over five million inhabitants, is the largest urban centre in Ethiopia, and road traffic crashes, constitute one of its significant problems. The steady increase in the number of heavy vehicles transporting construction and waste material associated with the booming construction activities exposed road users to high crash risk, exacerbating the road safety problem of the city.

In 2017, Ethiopia had 1,071,345 vehicles, of which 244,154 (about 23 percent) were heavy vehicles (Federal Transport Authority , 2019). Around 56 percent of vehicles in the country are registered in Addis Ababa, and the city also accounts for 82.3 percent of the country's heavy vehicles – a disproportionately high share. The heavy vehicle fleet in the city is characterized by old and poorly maintained vehicles, primarily made in China. Fatal crashes involving heavy vehicles, generally used for work-related trips, contributed to over 30 percent of all road deaths in Addis Ababa between July 2014 and June 2017. Heavy vehicles were involved in 8,253 road traffic crashes in the city during that period. In other words, about 8 heavy vehicle-related crashes occurred each day in the city in 3 years (Addis Ababa Police Commission, 2017) . Studies by Tulu (Getu Segni Tulu S. W., 2013; Getu Segni Tulu M. H., 2019) also showed that crashes involving heavy vehicles constitute a significant share of all crashes in the country. It is, therefore, not surprising that exposure to the risk of crashes involving heavy vehicles has become a significant preoccupation of road users in Addis Ababa. This concern is linked to the perceived dangerous interaction between these vehicles and road users. The growth of heavy vehicles combined with what many consider poor road safety practices, including inefficient fleet management, dangerous behaviour of drivers, and unsafe road environment, increases the risk of crashes in the city considerably. Reducing fatalities and injuries from heavy vehicle crashes requires understanding their causes, including the above factors' contribution. However, few in-depth studies have been undertaken on this category of crashes. The present study investigates heavy vehicle-related crashes in Addis Ababa from this perspective.

The study's main objective is to improve understanding of the factors contributing to heavy vehicle crashes in the city. It also seeks to determine the extent to which different factors contribute to the severity of the crashes measured in terms of fatalities, serious and slight injuries, and property damage. The study uses data for three years, from July 2014 to June 2017, and its methodology is presented in Section 2 of this article. It comprises the use of descriptive statistics and random parameter logit regression to identify the factors associated with heavy vehicle crashes and assess their contribution to the severity of the outcome of these crashes. Section 3 describes the data used in the analysis, while Section 4 presents and discusses the results. Section 5 concludes the article.

## 2. Literature review

Over the years, many researchers have been preoccupied with the factors that contribute to road crashes and the outcome of crashes in terms of the severity of injuries. In this regard, they have studied the association between crashes and time of the day, day of the week, age and education level of drivers, type of vehicle, road infrastructure, and weather conditions, among other variables. They have also studied the distribution of fatalities and injuries among different categories of road users and the enforcement of road safety laws, such as those governing speed limits.

Several studies have revealed that the time of the day significantly contributes to heavy vehicle crashes. For instance, a study in New York City found a significant association between afternoons and nights with heavy truck crashes with severe injury outcomes (Wei Sun, 2017; Wang, 2019; Jasmine

Pahukula, 2015). Researchers concerned about high rates of fatal crashes during weekdays have focused their attention on pre-crash factors during this period. In that regard, they have identified relatively low traffic volumes on the one hand and the prevalence of drink-driving at high speed on the other as contributing factors. A similar pattern of low traffic levels and dangerous road user behavior has been observed at night during weekdays (Debra Furr-Holden, 2011).

Regarding the influence of age on crashes, many associate young drivers with risky behaviour and traffic violations that increase their vulnerability to crashes. For instance, a study in South Africa found that younger drivers were involved in more crashes than older ones (Mohammed, 2015). Similarly, a study in the United States revealed that old drivers were much less likely to be involved in crashes (Richard Kent, 2005). Another study in Belgium confirmed that less experienced truck drivers have a problem with poor sleep quality during the day and at night which has negative safety implications (Lutgart Braeckman, 2011). In a nutshell, adult drivers are generally more experienced than younger ones, hence less likely to be involved in crashes with fatalities and/or injuries.

There is evidence that the level of education influences drivers' behavior and contributes to crashes. Less educated truck drivers, for instance, have higher exposure to crash risk than more educated ones. Driving is a complex process requiring visual, physical, and mental abilities to navigate the road environment. Drivers must have the skills and ability to interact with the vehicle, other road users, and the road environment simultaneously (Pradhan, 2013; Silva, 2014). These tasks demand intensive and critical thinking, which can be acquired through education. The efficiency of drivers in perceiving, processing, and interpreting information to make quick decisions when driving is influenced by their level of education (Starratt, 2014). Studies in Australia and South Africa have also revealed that drivers' education level affects their involvement in crashes (Mohammed, 2015; Teresa Senserrick, 2009). Education assists in developing critical thinking and modifies individuals' knowledge, behaviour, dispositions, and skills, all of which significantly affect driving, hence involvement in crashes (Stephen M. Fain, 2009).

The principle of kinetic energy has been used to explain the relationship between vehicle mass and the severity of crashes. This research has highlighted why crashes involving heavy vehicles are more likely to be fatal, assuming that speed is kept constant (Davoud Khorasani-Zavareh, 2015). There is also broad literature on infrastructure safety, with many studies recognizing the safety benefits of a road median, mainly raised medians (Wilson Mighk, 2008; Grant G. Schultz, 2011). In addition, researchers have explored various dimensions of the association between weather conditions and crashes. Anderson, for instance, found that good or clear weather is associated with weekend crashes involving heavy vehicles (Jason C. Anderson, 2017).

Some studies have focused on road safety in Addis Ababa. Compliance with speed limits is a significant challenge in the city. An observational study by John Hopkins University (John Hopkins University, 2019) on the compliance of posted speed revealed that 58 percent of heavy vehicles drive over the speed limit in Addis Ababa. Non-compliance with traffic laws is linked to weak enforcement by the police in many developing countries, partly due to a lack of resources (Nantulya, 2002; Nejat Anbarci, 2006; King, 2015; Heydari, 2019)[.

This section has shown that considerable research has been done worldwide on the factors influencing road crashes. This article contributes to the existing body of knowledge by focusing on heavy vehicle crashes resulting in fatalities and injuries in Addis Ababa. It explores the factors that explain the severity of the outcome of these crashes. The following section presents the methodology of the study.

## 3. Methods

### 3.1. Descriptive statistics

Descriptive analysis was used to characterize road crashes, identify possible causes, and examine the relationships between contributing factors. The association of several factors with heavy vehicle crashes was examined, including time of the day, day of the week, and the demography of road users, among others. For instance, the time variation of crashes was analysed to identify the most crash-prone hours of the day with the view to proposing appropriate measures to address the situation. The day of the week also influences crashes involving heavy vehicles as the activities of road users and traffic volumes often vary on different days of the week.

## 3.2. Analytical methodology

Injury severity is measured on an ordinal scale, and many researchers have applied ordered regression to identify the contributing factors to the severity of injuries from road crashes (Isaac Ofori Asare, 2020; Quan Yuan, 2020; Mohad Fedder Musa, 2020; Isaac Ofor iAsare, 2020; Mphekgwana, 2022; Shamsunnahar Yasmina, 2013; Xiaokun Wang, 2005; Ksaibati M. R., 2018; S.M. Rifaat, 2005) Although ordinal data can be modelled using an ordered probability model, some significant limitations are associated with readily available ordered models, which should caution against their use (Simon Washington, 2011). This article applies random parameter logit regression, which obviates the limitations of a standard ordered logit model due to unobserved heterogeneity by allowing random variations among the explanatory variables (Shikun Xie, 2020; Ghazaleh Azimi, 2020). While the random parameter logit model is a complex statistical methodology capable of identifying the unobserved characteristics of road users, its application on injury severity is limited. It is well known that the crash databases found in developing countries are associated with underreporting. Applying a complex statistical methodology allows this study to capture underreported injuries.

A random parameter logit model assumes that some parameters are random across the population (and sample). Model parameters can vary across the population with a pre-specified distribution, which accounts for unobserved heterogeneity across observations, such that (Simon Washington, 2011).

$$y_{ni} = \beta_{ni} X_n + \varepsilon_{ni}. \quad (1)$$

Where $X_n$ are explanatory variables (night time indicators, drivers' age, etc.) as a vector of estimable parameters, $\beta_{ni}$ is a vector of alternative-specific estimable parameters, some or all of which are varied across the population, and $\varepsilon_{ni}$ is the error term. It is possible to apply individual heterogeneity by varying random parameters across the population; for instance, drivers' age. On the other hand, non-random terms are fixed parameters that represent constants across the population. The estimable parameter can be written as:

$$\beta_{ni} = \mu_i + M\omega_n + \Gamma_i \eta_{ni} .. \quad (2)$$

Mixed logit probabilities are expressed as the integrals of multinomial logit probabilities over a parameter density. The probability expression of MNL is given by (Train, 2009):

$$P_{ni} = {EXP[\beta_{ni} X_n] \Big/ \sum_{j=1}^{i} EXP[\beta_{ni} X_n]} \quad (3)$$

Thus, the probability of the mixed logit model can be expressed as an integral of the equation

$$P_{ni} = \int \frac{EXP[\beta_{ni} X_n]}{\sum_{j=1}^{i} EXP[\beta_{ni} X_n]} f(\beta_i / \phi) d\beta \quad (4)$$

All other variables are defined in equation (1), and f(β/φ ) is a density function of β with φ referring to a vector of parameters of the density function (mean and variance).

## 3.3. Description of data

Addis Ababa has ten sub-cities, and the police department of each sub-city is responsible for collecting data on crashes. Data for heavy vehicle-related road traffic crashes were gathered from each sub-cities, police department, and Addis Ababa Police Commission from July 2014 to June 2017 (three years). Road traffic injuries in Ethiopia are classified into four groups fatal, serious, slight injuries, and property damage only (Getu Segni Tulu S. W., 2017). A road traffic crash is fatal if a road user involved in the crash dies within 30 days. In a serious injury crash, at least one person is hospitalized for 24 hours or more. In a slight injury crash, at least one person suffers from a road traffic injury that requires outpatient medical treatment or hospitalization for less than 24 hours. Property damage only refers to any vehicle crash other than an injury crash.

The Addis Ababa Police Commission investigates fatal crashes and, together with the police department of the sub-cities, keeps crash record books that register various attributes for each crash. The variables in the crash database include the time of day, day of the week, education, age and gender of drivers, driving experience, driver's relationship with vehicle (employee/owner/other), vehicle

service years, vehicle type, vehicle ownership, road type, land use, median and junction types, terrain, pavement type, pavement conditions, illumination, weather conditions, casualty type, crash location and reason for the crash. Currently, the crash data is available in hard copy. However, the city is in the process of digitalizing the data.

In this research, 33 variables were hypothesized to be associated with crashes involving heavy vehicles and thus included in the model as explanatory variables. The details of these variables and the frequency of their involvement in each category of heavy vehicle crashes (fatal crashes, injury crashes, and those resulting only in property damage) are presented in Table 1. A total of 8253 crashes are analysed.

**Table 1: Description of heavy vehicle crashes (July 2014-June2017)**

| Variables | Fatal crashes (%) | Injury crashes (%) | Property Damage only (%) | Total (%) |
|---|---|---|---|---|
| **Time** | | | | |
| Daytime | 245(66.58%) | 3447(83.34%) | 2900(79.58 %) | 6347(76.91%) |
| Nighttime | 123(33.42%) | 794(17.66%) | 744(20.42%) | 1661(23.09%) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Weekdays** | | | | |
| Weekdays | 276(75%) | 3388(79.89%) | 2937(80.6%) | 6325(76.64%) |
| Weekends | 92(25%) | 853(20.11%) | 707(19.4%) | 1928(23.36%) |
| **sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Driver's age (continuous variables)** | 368(100%) | 4241(100%) | 3644(100%) | 8253(100%) |
| **Driver's education level** | | | | |
| Elementary and below | 67 (18.20 %) | 342(8.06%) | 314(8.26 %) | 723(8.76%) |
| High school | 271(73.64 %) | 3416(80.55%) | 2975(81.64 %) | 6662(80.72 %) |
| Above high school | 30(8.15%) | 483(11.39 %) | 355(9.74%) | 868(10.52 %) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Vehicle driver relationship** | | | | |
| Employee | 320(86.96%) | 3636(85.73%) | 3244(89.02%) | 6880(87.25%) |
| Owner | 28(7.61%) | 400(9.43%) | 207(5.68 %) | 607(7.7 %) |
| Other | 20(5.57%) | 205(4.83%) | 193(5.3 %) | 3.98(5.05%) |
| **sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Heavy vehicle(truck) type** | | | | |
| Truck, truck with trailers &semi trailers, fuel truck (excluding dump truck) | 153 (41.58%) | 2137 (50.39%) | 1710(46.93%) | 4000 (48.47%) |
| Dump Truck | 215 (58.42%) | 2104 (49.61%) | 1934(53.07%) | 4253 (51.53%) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Vehicle ownership** | | | | |
| Private Individual | 316(85.87%) | 3741(88.21%) | 3249(89.16%) | 7306(88.53%) |
| Company, governmental and non-governmental | 52(14.11%) | 500(11.79%) | 395(10.84%) | 947 (11.47%) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Junction type** | | | | |
| Junction various type | 182(49.46%) | 1984(46.78%) | 1726(47.37%) | 3892(47.16%) |
| Midblock section | 186(50.54%) | 2257(53.22%) | 1918(52.63%) | 4361(52.84%) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Vehicle service years (continuous variable)** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Weather condition** | | | | |
| Good weather conditions | 342(92.94%) | 4006(94.46%) | 3476(95.39%) | 7824(94.80%) |
| **Other (**fog, rain, wind, etc.) | 26(7.06%) | 235(5.54%) | 168(4.61%) | 429(5.20%) |
| **Sub total** | **368(100%)** | **4241(100%)** | **3644(100%)** | **8253(100%)** |
| **Land use** | | | | |
| Schools, hospitals and religious areas etc. | 171(46.47%) | 2025(47.75%) | 1755 (48.16%) | 3951 (47.87%) |
| Industrial area | 9(2.45%) | 130(3.07%) | 80 (2.20 %) | 219 (2.65 %) |
| Office | 100(27.17%) | 1111(26.20%) | 983 (26.98%) | 2194 (26.58%) |
| Residential | 66(17.94%) | 807(19.03%) | 672 (18.44 %) | 1545 (18.72%) |
| Other | 22(5.98 %) | 168(3.96%) | 154 (4.23%) | 344 (4.17%) |
| **Sub total** | **368 (100%)** | **4241(100%)** | **3644(100%)** | **8253.00(100%)** |

Vehicle population data was also gathered from the Ethiopian Transport Authority.

## 4. Results and discussion

### 4.1. Descriptive analysis results

***Variation in crashes by time of day and day of week***

Heavy-vehicle crash counts in Addis Ababa vary by hours of the day. Most of these crashes, 92 percent, occur between 6:00 and 20:00. Peak crashes occur from 9:00 to 13:00 and from 14:00 to 16:00 (figure 1). The overrepresentation of daytime crashes could be explained by the fact that most construction activities take place during the day. Most crashes involving these vehicles occur during morning and afternoon working hours. Heavy vehicle crashes drop during lunchtime (from 13:00 to 14:00), as shown in figure 1. In other words, drivers' exposure to crashes declines during the lunch break.

Interestingly, a study by Delhi Integrated Multi-Modal Transit System (DelhiIntegrated Multi-Modal Transit System, 2018), an Indian consulting firm, demonstrated a pattern in the variation of truck volume in Addis Ababa during the day, shown in figure 2, that is similar to the pattern of heavy vehicle crash counts. The striking similarity of figures 1 and 2 suggests an association between heavy-vehicle crashes and truck volumes in Addis Ababa. In this regard, more crashes occur during periods of the day with a higher circulation of trucks.

**Figure 1: Variation of heavy vehicle crashes by hours of day**

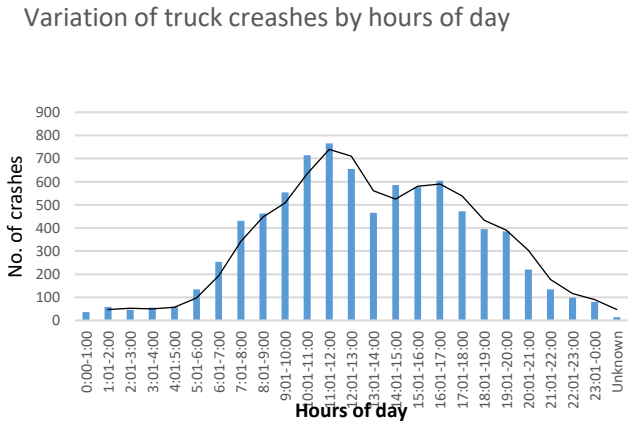
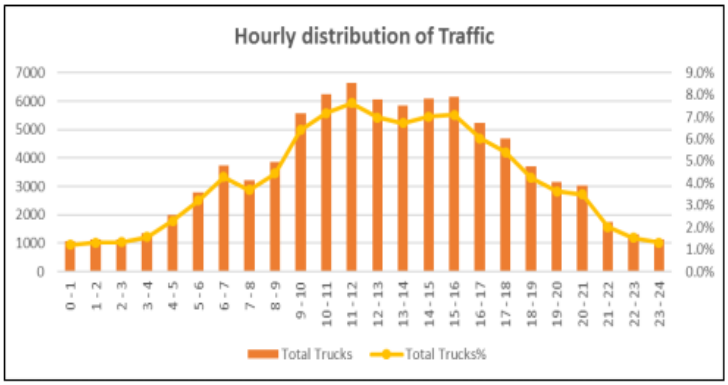



**Figure 2: Hourly distribution of freight traffic**




*Source*: (DelhiIntegrated Multi-Modal Transit System, 2018)

The total number of crashes per day of the week, categorized by the severity of the outcome, is presented in table 2. There is little difference in the number of daily crashes during weekdays. Vehicle kilometres travelled per day and the share of heavy vehicles in traffic volume, were high on weekdays

compared to weekends. In contrast, the number of crashes during weekends was relatively small. In particular, the number of crashes reduced by more than fifty percent on Sundays compared to weekdays and Saturdays. The likely explanation is that fewer heavy vehicles are driven during weekends when fewer construction activities occur, and many businesses are closed.

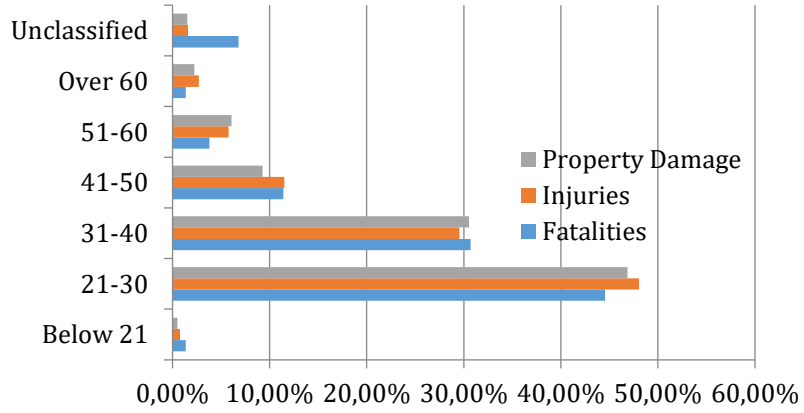
**Table 2: Heavy vehicle crashes by days of the week**

| Day of week | Fatal | Injury | Property damage | Total crashes |
|---|---|---|---|---|
| Monday | 67 (18.21%) | 675 (15.92%) | 610(16.74%) | 1352(16.38%) |
| Tuesday | 43(11.68%) | 705(16.62%) | 584(16.03%) | 1332(16.14%) |
| Wednesday | 51(13.86%) | 665 (15.68%) | 611(16.77%) | 1327(16.08%) |
| Thursday | 56(15.22%) | 644 (15.19%) | 519(14.24%) | 1219(14.77%) |
| Friday | 59(16.03%) | 699(16.48%) | 614(16.85%) | 1372(16.62%) |
| Saturday | 47(12.77%) | 576(13.58%) | 502(13.78%) | 1125(13.63%) |
| Sunday | 45(12.23%) | 277(6.53%) | 204(5.60%) | 526(6.37%) |
| Total | 368(100%) | 4241(100%) | 3644(100%) | 8253(100%) |

***Drivers' age and gender***

There is a relationship between drivers' age and their involvement in heavy vehicle crashes. In this regard, drivers in the 21-30 and 31-40 age groups were associated with a disproportionately high number of crashes resulting in fatalities and injuries and those resulting only in property damage. Combined, these two age groups accounted for nearly 80 percent of all crashes in the city. Drivers aged 41 or older had less severe crashes than those between the ages of 21 and 40.

**Figure 3: Heavy vehicle crashes distributions by drivers age group**




The driving licensing scheme in Ethiopia may explain the prevalence of crashes involving young heavy vehicle drivers. Before 2008, the scheme was progressive, and candidates must pass three certification stages to qualify as truck drivers. However, the country has amended the driver's qualification certification law under Proclamation No. 600/2008 (The Federal Republic of Ethiopia, 2008). The amendment of the licensing scheme has perceived limitations, such as allowing young drivers to qualify for a truck driving license directly – without prior qualification for driving lower categories of vehicles.

Regarding gender, Ethiopia's proportion of females with driving licenses is insignificant. For instance, only 14.4 percent of licensed drivers in Addis Ababa are female. The share of female licensed drivers is even smaller at the national level, just 11.1 percent (Federal Transport Authority , 2019). Similarly, female professional drivers who operate heavy vehicles are very rare. Table 3 shows that the involvement of female truck drivers in fatal, injury, and property damage crashes is almost nil.

**Table 3: Heavy vehicle crash count distribution by gender**

| Gender of drivers | Fatal | Injury | Property Damage Only | Total |
|---|---|---|---|---|
| Male | 368(100%) | Total | 3642(99.95%) | 8240(99.84%) |
| Female | 0(0%) | 11(0.26%) | 2(0.05%) | 13(0.16 %) |
| Subtotal | 368(100%) | 4241(100%) | 3644(100%) | 8253(100%) |

## 4.2 Random parameter logit regression analysis results

The results of the multinomial regression analysis of crashes involving heavy vehicles in Addis Ababa are presented in table 4. Parameters of each variable were tested to find a positive or negative association with crashes at 1, 5, and 10 percent significant levels. The best statistical fit model was found using a likelihood ratio test. In the analysis, the heavy vehicle crashes – categorised as fatal crashes, injury crashes, and crashes with property damage only – were considered as the dependent variable, and the property damage only category was selected as the reference.

**Table 4: Random parameter logit model output**

| Variables | Fatal | | | | | Serious | | | | | Slight | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coef. | Std. Err. | Z | P>\|z\| | [95% Conf. Interval] | Coef. | Std. Err. | Z | P>\|z\| | [95% Conf. Interval] | Coef. | Std. Err. | Z | P>\|z\| | [95% Conf. Interval] |
| **Random parameter variables** | | | | | | | | | | | | | | | |
| Driver's age (continuous variables) | 0.014*** | 0.004 | 3.36 | 0.001 | [0.006, 0.023] | | | | | | | | | | |
| Std. dev. of distribution | 0.002 | 0.04040 | 0.04 | 0.967 | [-0.078, 0.081] | | | | | | | | | | |
| Nighttime (1 if true; 0 otherwise) | | | | | | -0.864*** | 0.116 | -7.44 | 0.000 | [-1.092, -0.639] | | | | | |
| Std. dev. of distribution | | | | | | 0.023 | 0.485 | 0.05 | 0.962 | [-0.927, 0.974] | | | | | |
| **Non-Random parameter variables** | | | | | | | | | | | | | | | |
| **Constant** | **1.382*** ** | **0.222** | **6.22** | **0.000** | **[0.947, 1.817]** | **1.518*** ** | **0.211** | **7.20** | **0.000** | **[ 1.105, 1.931]** | **-0.281*** | **0.167** | **-1.67** | **0.094** | **[-0.610, 0.049]** |
| Driver's age | | | | | | **0.012*** ** | **0.004** | **2.88** | **0.004** | **[0.004, 0.02]** | | | | | |
| Nighttime (1 if true; 0 otherwise) | **-0.719*** ** | **0.116** | **-6.21** | **-0.000** | **[-0.947, -0.492]** | | | | | | **-0.512*** ** | **0.152** | **-3.36** | **0.000** | **[-0.810, -0.213]** |
| Driver's education: high school (1 if true; 0 otherwise) | **0.501*** .** | **0.127** | **3.94** | **0.000** | **[0.252, 0.750]** | **0.618*** ** | **0.141** | **4.38** | **0.000** | **[0.341, 0.894]** | **53138*** ** | **0.163** | **3.25** | **0.001** | **[0.211' 0.851]** |
| Driver's education: Degree | | | | | | **0.286*** ** | **0.104** | **2.76** | **0.006** | **[0.083, 0.489]** | | | | | |
| Driver's relation with vehicle_ owner | -0.526*** | 0.092 | -5.67 | 0.000 | [-0.707 - 0.344] | | | | | | | | | | |
| Dump truck (1 if true; 0 otherwise ) | 0.183* | 0.111 | 1.65 | 0.099 | [-0.034, 0.401] | 0.289*** | 0.111 | 2.60 | 0.009 | [0.071, 0.507] | 0.518*** | 0.141 | 3.67 | 0.000 | [0.241, 0.795] |
| Straight road without bending 1 (if true; 0 otherwise) | 0.165* | 0.096 | 1.71 | 0.087 | [ -0.024, 0.354] | | | | | | | | | | |
| Intersections that have 4 legs and above (1if true; 0 otherwise) | 0.099* | 0.060 | 1.65 | 0.099 | [ -0.018, 0.217] | | | | | | | | | | |
| Other types of intersection | 0.171 | 0.119 | 1.43 | 0.153 | [-0.063, 0.404] | | | | | | | | | | |
| Weekend | 0.058 | 0.055 | 1.04 | 0.298 | [-0.051 ,0.168] | | | | | | | | | | |
| Presence of median | 0.170* | 0.103 | 1.65 | 0.099 | [-0.032, 0.373] | | | | | | | | | | |
| | | | | | Random Parameter logit regression Number of obs =8253<br>Log likelihood at start= -8407.044<br>Log likelihood at final = -8387.86<br>Pseudo R2 = 0.272 | | | | | | | | | | |

The model identified 8 explanatory variables influencing fatal crashes involving heavy vehicles in Addis Ababa with p-critical values at 0.01, 0.05, and 0.1. Similarly, 5 variables were found to influence serious injury crashes involving heavy vehicles, and 3 influenced slight injury crashes. The model shows that the log-likelihood at zero is -8407.0444 and at convergence is -8327.8616, which gives a Pseudo $\rho^2$ of 0.272, indicating a reasonable fitness level. These effects are discussed below.

***Time of the day***

The coefficient of the variable for driving at night (nighttime) indicates that it is negatively associated with fatal crashes involving heavy vehicles with a p-value that is less than 0.01. This implies that the probability of fatal crashes involving heavy vehicles occurring at night is lower than that for crashes involving property damage only. Figure 1 also illustrates a high level of crashes during the day. Figure 2 shows that the hourly distribution of freight traffic volume indicates very high volumes during the day (DelhiIntegrated Multi-Modal Transit System, 2018). In essence, the likelihood of fatal crashes increases in the daytime due to the high traffic volumes and heavy vehicle drivers' tendency to drive at higher speeds off pick hours during the day. This finding supports other studies that have also revealed that the time of the day significantly contributes to heavy truck crashes (Wang, 2019; Wei Sun, 2017; Jasmine Pahukula, 2015).

Concerning crashes resulting in slight injury, the coefficient of the variable for driving at night (nighttime) is negative with a p-value of less than 0.01. This implies that the likelihood of crashes with slight injuries occurring at night is lower than those resulting only in property damage which is the reference group in the analysis. This indicates that more injury crashes involving heavy vehicles occur during the day than at night.

***Characteristics of demography of drivers***

Driver's age is a continuous explanatory variable in the model and is positively associated with fatal crashes involving heavy vehicles in the best-fit statistical model with a p-value of less than 0.01. The likelihood of crashes resulting in fatalities increases slightly compared to crashes resulting only in property damage as the age of drivers increases. Similarly, a driver's age has minor effects on road users' likelihood of serious injury from crashes with a heavy vehicle. The variable has a positive coefficient and a p-value of less than 0.01. This implies that the likelihood of crashes with serious injury increases relative to crashes with only property damage as the age of drivers increases. However, as indicated in Section 4.1, it is worth noting that older drivers are involved in fewer and less severe crashes than younger ones. Overall, there seem to be mixed findings in the literature on the relationship between drivers' age and their involvement in crashes. A study in South Africa, mentioned in the literature review section of this article, demonstrated that older drivers are involved in fewer crashes than younger ones (Guang X Chen, 2014). On the contrary, a study in the United States revealed that old drivers were much more likely to be involved in crashes (Newnam, 2018). These mixed results support the view that the effect of age on crashes varies across drivers and that several factors may affect the sensitivity of age to crashes.

Heavy vehicle drivers whose education status is the high school level or below are positively associated with fatal crashes with a p-value of less than 0.01. This means that drivers in this category are more susceptible to fatal and serious truck crashes than crashes resulting only in property damage. This finding supports those of studies in Australia and South Africa that have revealed that the level of education of drivers affects their involvement in crashes (Mohammed, 2015; Teresa Senserrick, 2009). Education helps develop critical thinking and modifies individuals' knowledge, behaviour, dispositions, and skills, which significantly affect driving, hence involvement in crashes (Stephen M. Fain, 2009).

***Drivers' relationship with trucks***

Heavy vehicles driven by the owner are negatively associated with fatal crashes with a p-value of less than 0.01. Owner drivers are less likely to be involved in fatal crashes than crashes resulting only in property damage. On the contrary, employee drivers are more prone to fatal crashes, partly because of misuse of vehicles. M. Owners closely monitor the roadworthiness of their vehicles and the conditions of the roads on which the vehicles operate. They generally respect preventive maintenance schedules and undertake proactive maintenance of their vehicles. In contrast, there is a general perception that heavy vehicles driven by employees or others are not monitored rigorously. Instead, employee drivers

negotiate with vendors to overload vehicles - beyond the loading capacity – to benefit from extra loading charges. Travel for unauthorized tasks and other abuses are also perceived to be typical for trucks operated by employee drivers. This further increases the risk of involvement in fatal crashes. However, companies and government organizations in Ethiopia increasingly use modern fleet management methods, including vehicle tracking technology, which enable them to trace goods and the amount of fuel in trucks, improve vehicle scheduling, and control and improve the efficiency of delivery processes. Controlled use of vehicles could reduce their involvement in road traffic crashes.

This study found that dump trucks are positively associated with serious and slight injury crashes with p-values of less than 0.01. This means that dump trucks are more likely to be involved in both categories of crashes than crashes resulting only in property damage.

***Road median***

The presence of a median in the road network is found to be positively associated with the occurrence of fatal crashes involving heavy vehicles. The association is mild, with a p-value of less than 0.5. The finding indicates that the presence of the median could increase the probability of fatal crashes compared to crashes that result only in property damage. The separation of incoming and outgoing traffic may encourage truck drivers to drive at higher speeds, which exposes them to higher fatal crash risk. It is common practice for truck drivers in Addis Ababa to exceed speed limits. A study by John Hopkins University (2019) showed that 58 percent of heavy vehicles drive over the speed limit in Addis Ababa (John Hopkins University, 2019). However, several other studies found that the presence of a median contributes to the safety of road users. This is because it separates incoming and outgoing traffic, which assists in avoiding head-on collisions. Another benefit is that it serves as a refuge island for pedestrians crossing roadways. In the case of Addis Ababa, some medians are painted or constructed with kerbstones, both of which are unsafe for various reasons. First, kerbstone medians in the city cannot serve as refuge islands because they have no space for pedestrians to stand (usually, they have a width of 15 to 17cm). Second, there is widespread violation of rules and regulations by drivers in Addis Ababa, particularly concerning medians in the form of road markings. It is common practice to drive on the market median in the city as the level of traffic enforcement is weak. The weak enforcement and resource problems of police have been confirmed in many developing countries (Nantulya, 2002; Nejat Anbarci, 2006; King, 2015; Heydari, 2019).

***Straight roads***

Tangent roads were found to be positively associated with fatal crashes involving heavy vehicles during the three years for which crashes were investigated. The association is weak, with a p-value of less than 0.1. This finding implies that truck drivers may be exposed to fatal crashes in tangent sections of the roads. This is attributed to the high speed with which they operate during the day. A similar study in the country confirmed the correlation between tangent sections of roads and the occurrence of fatal truck crashes [7]. The road environment (geometry) is less complex, and driving tasks are more straightforward in tangent sections. As a result, drivers may be less focused when they navigate these sections.

***Intersections with 4 legs and above***

Intersections with four legs and above are found to be associated with fatal truck crashes. The association is mildly significant, with a p-value of less than 0.1. Intersections are complex road environments where one or more users share the same space (Nightingale, 2017). There are at least 32 conflict points on four-leg intersections, which increases as the number of approach legs increases (Arun, 2021).

## 5. Discussion

A key finding of this study is that heavy vehicle-related crashes are common in Addis Ababa, constituting over 30 percent of the total road traffic crashes in the city between July 2014 and June 2017. Fifty percent of heavy vehicle-related fatal crashes in the city involve dump trucks which are often used for construction activities. However, policymakers in Addis Ababa seem to have a high tolerance for unsafe practices. For example, heavy vehicles are generally not allowed to operate in the city during

peak hours of the day (from 7:00 to 9:30 and 16:30 to 18:00). However, due to the demand of the construction industry and other activities, the authorities and Police Commission often give special permission for them to access the city during these times.

Crashes involving heavy vehicles are generally work-related and mostly occur during working hours on weekdays. Moreover, severe crashes, particularly those resulting in the deaths of pedestrians, occur mostly in the daytime and during weekdays. This could be linked to the prevalence of work-related trips and the high speed of trucks as they deliver construction inputs to the city and carry waste to its outskirt. Excessive speeding by drivers of heavy vehicles is prevalent in the daytime and during weekdays compared to nights and weekends. This suggests the need for vigorous enforcement of speed and other road traffic laws, particularly during these high-risk periods. However, this is not the case, as the traffic police that enforces these laws in Ethiopia seem to be under-resourced, just like in other developing countries [28,29]. The Addis Ababa Police Commission is equipped with breathalysers and speed guns that could help solve the problem, but it has limited quantities of this equipment on the one hand, and their use is generally ineffective on the other. In this regard, there are concerns that devices such as speed guns are not properly maintained and calibrated, which erodes public trust in their effectiveness.

Several factors may explain the weak, inefficient, and ineffective enforcement of traffic rules and regulations in Addis Ababa. For instance, the number of traffic police officers in the city is insufficient to ensure visible enforcement of traffic rules and regulations and deter and change road users' illegal and unsafe traffic behaviour. The monthly income of police officers is also perceived to be very low compared to the prevailing market wage and high living costs in the city. Moreover, there are inconsistencies in traffic regulations among the regional States of Ethiopia, and fines for traffic offenses are perceived to be low and therefore fail to deter offenders from unsafe practices (John Hopkins University, 2019). For instance, a driver could get a financial penalty of US$ 3.50 (180 Ethiopian Birr) for driving under the influence of alcohol (Council of Ministers of Ethiopia, 2017). Similarly, the penalty for excessive speeding is less than 5 US$ (250 Ethiopian Birr). Furthermore, there is a high turnover of trained traffic police officers.

Another key finding of this study is the disproportionately high involvement of young drivers in heavy vehicles in fatal and non-fatal crashes in the city. In this regard, drivers in the 21-30 age group are the most susceptible to crashes, followed by those in the 31-40 years group. In essence, older drivers are less likely to be involved in severe crashes (fatal and injury crashes) than younger ones. However, old drivers are few, which may explain the lower share of crashes in which they are involved. Lack of data is a challenge in analysing the exposure of drivers of different age groups in crashes.

Various reasons have been postulated for the high involvement of young drivers in crashes, including inexperience, poor driving training, testing schemes, and factors related to adolescent development. Young drivers are generally associated with risky behaviour and traffic violations that increase their vulnerability to crashes. Concerning training, the driver licensing scheme in Ethiopia appears to be problematic. Under Proclamation 200/2008, all citizens of the country are eligible to have a freight or professional/commercial driving license at 18. The proclamation seems to ignore the complexity of driving tasks and the workload required for different categories of vehicles. For instance, young citizens can have licenses to drive heavy vehicles without prior experience in driving lower categories of vehicles (lighter vehicles). In other words, the driver licensing scheme in the country is not hierarchal. This is the case despite the general acknowledgment that young drivers are not well experienced in vehicle handling and that their judgment, situational and risk awareness could be weaker or lower than those of older drivers. Given these concerns, it may be worth re-examining the minimum age of professional drivers in Ethiopia, considering international practice. A report by the United Nations Department of Economic and Social Affairs shows that almost 82 percent of the population of Ethiopia is below the age of 40 (UN Department of Economic and Social Affairs Population Division, 2022), and the driver's population follows a similar pattern to the demographic distribution of the country. This confirms that the driver population in the city is very young, hence the high involvement of young drivers in fatal and serious injury crashes.

This situation is compounded by what many perceive as inadequate driver's training in the country. The driver's training curriculum is considered to be flawed in terms of its content and duration of the training. Also, the facilities and competence of the instructors in driver's training schools across the country are questionable. There are flaws in the organisation and delivery of the theoretical and

practical training in these schools, and the time allotted for the entire exercise is less than 60 hours, which seems insufficient. The minimum required time for training for automobile driving is 60 hours - 40 hours of theory and 20 hours of practice (Federal Road Transport Authority , 2014). Also, the training curriculum does not include ethical aspects, defensive driving, traffic psychology, and essential post-crash response. Corruption and forgery in driver licensing have also been identified as critical problems in the system (United Nations Economic Commission for Africa and Economic Commission for Europe, 2018; Gashu T, 2018). This might be because the driver licensing and the driver offender systems are not computerized. The practice of filing data manually in a decentralised manner at each regional State in the country makes it hard to strictly check forgery and apply the demerit point system.

Overall, it seems that crucial road safety stakeholders – including the industry, regulators, and governments, in the past, have overlooked the causes of crashes in their prevention efforts and given more attention to regular training of drivers (Ahmed Fathalla Elshamly, 2017). It is encouraging that the government of Ethiopia is now taking steps to address the problems plaguing the country's driver's training scheme as part of reorganizing its transport system. A new driver's licensing law has been formulated in that regard (Proclamation No.1074/2018). However, the regulations and directives to establish a better driver's training and testing scheme in the country are still underway.

Drivers' education is another influential factor in fatal crashes involving heavy vehicles. Less educated truck drivers have higher exposure to crash risk than more educated ones. For instance, drivers with a high school level of education or lower are highly involved in fatal and serious crashes, which is not the case for those with a higher level of education. As mentioned earlier, driving is a complex process that demands intensive and critical thinking, which can be acquired through education. There is a need to ensure that all professional drivers meet driving requirements. They should be mentally and physically fit. In this regard, it is worth exploring the possibility of revising the minimum level of education for professional drivers in Ethiopia.

An interesting finding of this study is the contribution of the median of roads in Addis Ababa to crashes. Generally, median types and their safety performance vary with road user behaviour and the level of enforcement of rules guiding their use. For instance, road markings are not respected by most motorists in Addis Ababa, and traffic police officers do not strictly enforce compliance with such markings by penalizing those who violate them. It has been observed that they devote more attention to controlling traffic due to the increase in car ownership and serious congestion during rush hours in the city. The local Road Authority tends to use kerbstones to construct medians, but this is flawed as their dimension usually range from15 to17cm and therefore fail to serve effectively as pedestrian refuge islands. This exposes pedestrians to crashes when they cross the road. Given the well-documented benefits of medians elsewhere in the world, there seems to be scope to improve the design of medians in Addis Ababa.

This study did not examine the role of truck age in heavy vehicle crashes. This may be an essential line of inquiry given that the vehicle fleet in Ethiopia is generally old, and the country does not pose any restriction on the age of imported vehicles. Used cars constitute 85 percent of the vehicle fleet in Ethiopia. A large share of the used vehicles imported to most African countries, including Ethiopia, cause significant road safety issues and result in increased emissions due to lack of or weak enforcement of national vehicle standards and regulations in these countries. The import of sub-standard used vehicles not only impacts vehicle occupants but also reduces the safety of other road users.

## 6. Conclusions

This article has analysed the extent to which different factors influence the occurrence and severity of the outcome of heavy vehicle crashes in Addis Ababa. The analysis shows that these vehicles pose a significant risk to the safety of road users in the city during the day when fatal crashes are common. This is attributed to weak enforcement of speed limits. The analysis also shows that the risk of heavy vehicle crashes is associated with driving experience. In this regard, young drivers tend to be involved in more fatal and injury crashes than older ones, with crash tendency decreasing with increasing age of drivers. In addition, the article identifies the lack of raised medians with sufficient width to serve as pedestrian refuge islands as a risk factor for pedestrians. Other contributing factors to fatal crashes include the prevalence of trucks driven by employee operators, straight roads, and intersections that have four approach legs and above.

The following recommendations are drawn from the analysis in this article:

- Addis Ababa city Police Commission should strictly enforce speed limits on tangent sections of highways and alcohol limits for drivers. They should also provide adequate traffic safety equipment, including speed guns, breathalysers, and vehicles, to the traffic police. In addition, traffic police officers should be trained in evidence-based road policing in the city;
- Age and experience should be considered in the certification of professional and commercial drivers and heavy vehicle drivers in Ethiopia. The driver's training and licensing scheme in the country should be based on international best practices;
- Policymakers in Addis Ababa should promote the use of heavy vehicle tracking systems. Consideration could be given to the provision of incentives for the use of such systems;
- The Addis Ababa Road Authority should revise the current practice and design guide for road medians to incorporate pedestrian refuge islands at regular intervals for road sections with high levels of pedestrian movement;
- Traffic rules should be strictly enforced at complex intersections, and
- Government agencies and private companies that operate heavy goods vehicles should introduce Company Risk Assessments practices where road safety experts analyse their crash records to identify the most relevant risk factors. The aim is to evaluate the company's road safety culture and identify the company and employee-level strategies to reduce crashes.

It is worth noting that some of these recommendations are addressed in the national road safety strategy of the Federal Democratic Republic of Ethiopia launched in July 2022 (Federal Democratic Republic of Ethiopia, 2002).

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