

Enhancing Road Safety: Evaluating the Impact of Bus Tracking and Speed Control Systems on the Dar es Salaam to Dodoma Corridor in Tanzania

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Abstract Transportation in Tanzania comprises several modes, with road transport being one of the most prominent. Public road transport primarily involves inter-regional travel by buses, which carry both passengers and goods between regions. However, road crashes have significantly impacted transportation in Tanzania, with regional buses being involved in numerous accidents. Road safety has become a critical issue, as the consequences of road crashes extend beyond fatalities to include the destruction of buses and damage to highway infrastructure, such as road signs, posts, and markings. This increases the need and cost of highway maintenance. The study examines the effectiveness of a vehicle tracking system as a method to reduce road crashes. This system was introduced to monitor and control the speed of regional buses. It operates by alerting drivers when they exceed the speed limit, set at 80 km/h on the device. If a driver exceeds this limit, the system sends information to the nearest traffic office along the bus route. The study further suggests improvements to enhance the functionality of these devices to better reduce road crashes and improve safety for all road users. Descriptive research designs were used to collect and analyze crash data for all regional buses operating along the corridor.

Keywords Transportation, Crashes, Vehicle tracking system, Tanzania

1. Introduction

Road transport is one of the most commonly used modes of transportation in Tanzania. The regional movement of people via road transport is facilitated by privately owned regional buses, which typically have a carrying capacity of 30 to 50 passengers. These buses operate across the country, with ticket prices regulated by the Land Transport Regulatory Authority (LATRA). For instance, ticket prices for travel from Dar es Salaam to Dodoma range from 19,000 TSH to 40,000 TSH, depending on the service level of the bus. The service levels are categorized as luxury, semi-luxury, and normal. Regional buses primarily operate on trunk roads managed by the Tanzania National Roads Agency (TANROADS). Some of these roads are paved, while others remain unpaved. The total length of paved trunk roads is approximately 7,291.2 km [17].

Bus stands are available in all major regions and serve as drop-off and pick-up points for these buses. The buses are assigned to specific routes that follow the network of trunk roads across the country.

Regional buses face several challenges during their daily

operations, with crashes being one of the most significant. These crashes occur as buses travel from one point to another, resulting in negative impacts on road users. The causes of these crashes are varied. According to [5], less than 10% of crashes are attributed to environmental factors such as weather or road conditions, while more than 90% are caused by human factors, including reckless driving and speeding.

Speeding whether exceeding the posted speed limit or driving at inappropriate speeds for prevailing conditions significantly increases the likelihood and severity of crashes [13]. Road crashes are identified as a major cause of fatalities, often resulting in the deaths of many people at once and causing damage to highway infrastructure [5].

The Surface and Marine Transport Regulatory Authority (SUMATRA) implemented measures to reduce these incidents by addressing human factors. This was achieved through the introduction of bus tracking and speed control devices under the Vehicle Tracking System (VTS).

2. Literature Review

Road transport, compared to other modes of transportation, is more flexible, relatively cheaper, and faster. It also has a high capacity for carrying goods over short distances. However, one major disadvantage of this mode is the cost of maintenance [11]. Road safety, a crucial aspect of road transportation, involves the interplay between the driver,

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vehicle, road, and environment [16]. In Tanzania, some common causes of road crashes include overloading vehicles, speeding, drunk driving, mobile phone use while driving, poor infrastructure, animal crossings, running red lights, driver distractions (caused by internal or external factors), and adverse climatic conditions.

The severity of crashes indicates how serious the crash was. In Tanzania, road transport accommodates 80% of all passengers [4], meaning that crashes often involve a significant number of people. The severity of road crashes can be categorized into three main levels: fatal, injury, and property damage [7].

The Vehicle Tracking System (VTS) is a system that enables the tracking and control of vehicles through an online computer that provides real-time information about a vehicle's location, details, and speed. The system involves installing a device inside the vehicle, which is connected to a control room at the control centre. These devices send information to SUMATRA offices when buses exceed the speed limit of 80 km/h, which requires a stopping distance of 55 meters once the brakes are applied [14]. The device installed in the vehicle consists of a global positioning system (GPS) and a speed sensor with an alarm system. The GPS operates using a trilateration technique, which calculates location, velocity, and elevation by collecting signals from satellites [3]. Before the introduction of VTS, speed control was managed using speed governors. These devices were installed in vehicles to limit their speed by restricting fuel flow [18]. The speed of vehicles was regulated and confined to the limits prescribed by traffic regulations [15].

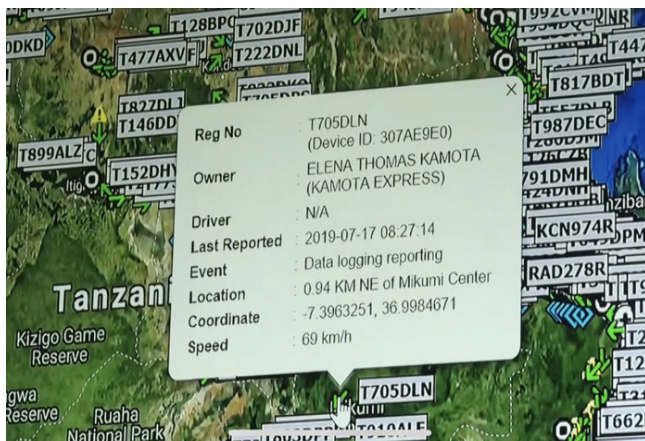


Figure 1. Information of a regional bus displayed on Vehicle tracking system

The Vehicle Tracking System (VTS) in Tanzania operates by connecting the Traffic Police Office and LATRA. Each major regional bus stand and traffic police office is equipped with a control room featuring a large screen that displays a map of Tanzania, including all regional bus routes. A bus symbol indicates the location of each bus, along with relevant information such as the driver's name, vehicle details, speed, and owner. The system also calculates the time taken by the bus on its route, enabling transit agencies to improve their management and service levels. Additionally,

the system allows passengers to plan their journeys more effectively [20].

In the 1990s, the Israeli government reformed public transportation, allowing more companies to enter the sector. This led to 18 official public bus companies and numerous private operators [22]. Increased competition has driven the adoption of safety technologies like tracking and speed control devices. Studies, such as [21], show that competition encourages operators to invest in safety innovations to attract passengers, comply with regulations, and enhance their reputation. This highlights the need for regulatory frameworks to incentivize such technologies, improving road safety.

3. Methodology

The study used an ordered logit regression model. Since many transportation applications involve ordered discrete data, the ordered logit regression model was applied to examine the relationship between attributes such as speeding, driver's age, reckless driving, vehicle malfunction, day of the week, and time of day, and the severity of crashes [19] [10]. The study involved two types of data: primary data and secondary data. According to [1], data collected through surveys, interviews, case studies, and problem-solving are called primary data because they are obtained firsthand, while data collected using desk research are called secondary data, as they are obtained from other sources. The secondary data collected consisted of qualitative data, including crash data from regional traffic officers and average daily traffic data obtained through documentary review. Primary data included the number of regional buses using the devices and the mode of operation of vehicle tracking and speed control devices in Tanzania. These data were collected through interviews with the director of the safety department at LATRA. The collected data were analyzed and summarized using tables, charts, graphs, and textual descriptions through descriptive analysis. The research design was developed after identifying the research problem. The design required a conceptual framework to maximize data yield, ensuring that data collection was conducted efficiently in terms of time and cost [6].

4. Data Processing, Analysis and Discussion

4.1. Data Processing

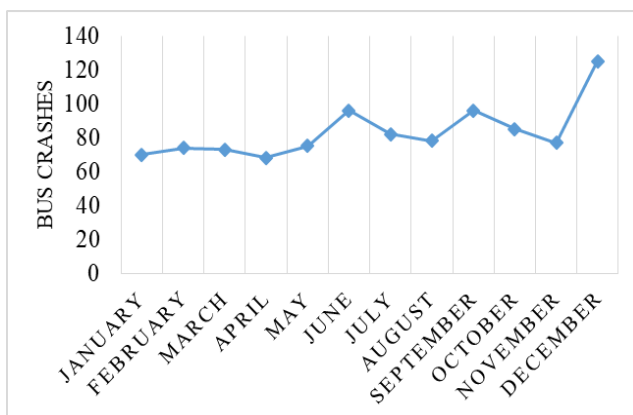
Regional bus crash data were collected from 2015 to 2020 (i.e., the years before the introduction of the vehicle tracking system (2015 to 2017) and after the introduction of the system (2018 to 2020)). Descriptive analysis was conducted to identify the months with the highest number of crashes. December had the most crashes, as people tend to travel more during the holiday season at the end of the year. June and September recorded the second highest number of crashes, following December.

Table 1. Number Crashes for regional buses

YEAR	NUMBER OF CRASHES
2015	180
2016	205
2017	229
2018	145
2019	126
2020	114

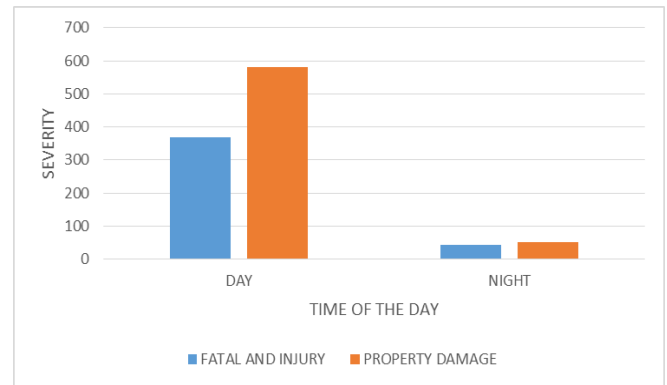
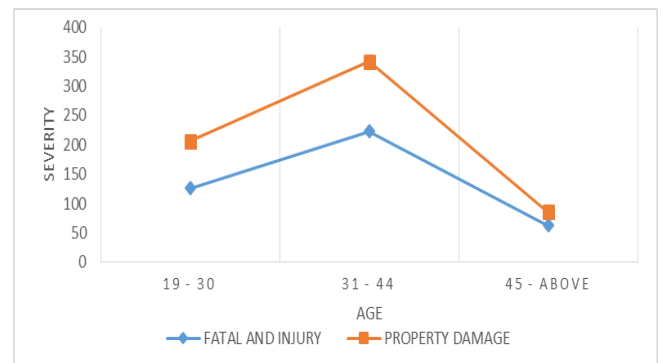
The crash data were processed in various ways to provide meaningful information for the study, linking different variables such as: severity distribution of bus crashes on a yearly basis, severity distribution of bus crashes on a monthly basis, distribution of crash severity along the corridor during different days of the week, crash severity during different times of the day, crash severity based on gender, causes of regional bus crashes on a yearly basis, monthly distribution of causes of regional bus crashes, crash severity based on age group, and the distribution of speed and reckless driving by age group.

The monthly distribution of bus crashes shows that December records more road crashes over a period of six years along the corridor from Dar es Salaam to Dodoma, while April records fewer road crashes along the same corridor during the same period.

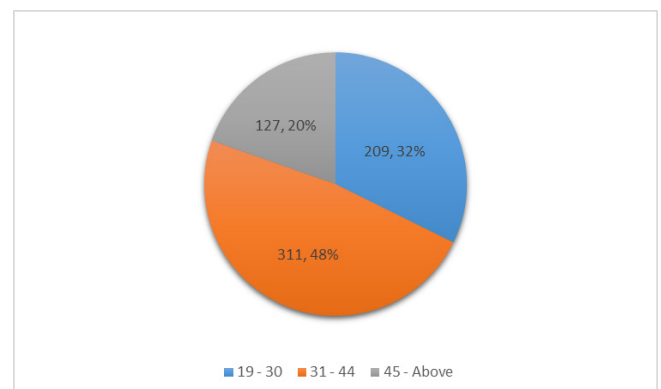
**Figure 2.** Monthly distribution of bus crashes in Tanzania

Regional buses operate at both times of the day: during the day and at night. Some buses start from the northern part of the country and take up to 17 hours to complete their journey, although the government has restricted very late movement of regional buses for security reasons. Daytime experiences more bus crashes compared to nighttime along the corridor.

Different age groups have distinct characteristics along the road, especially among drivers. The age group of drivers between 31 and 44 years recorded higher severity in regional bus crashes from 2015 to 2020. Older drivers (45 years and above) tended to have fewer collisions, as they adhered more closely to speed limits compared to younger drivers [9].

**Figure 3.** Severity distribution on time of the day**Figure 4.** Crash severity on age group basis

Driver performance is affected by age; older drivers have reduced response times for far and near point acuity, stereopsis, a measure of lateral and vertical vision, color vision, and spatial contrast sensitivity [9]. Most older drivers do not over-speed or drive recklessly, as their muscles may be weaker, making it harder for them to turn the steering wheel quickly, react rapidly, or apply the brakes in time [9]. Middle-aged drivers are the group most prone to reckless driving and speeding, as their minds are sharp and influenced by youthful tendencies. A total of 520 crashes caused by speeding and reckless driving involved drivers under 45 years old (80% of the crashes).

**Figure 5.** Speed and reckless driving distribution on age group basis

4.2. Data Analysis

The study used an ordered logit regression model. The model was derived by defining an unobserved variable, z , which is a linear function of all observations [19].

$$z = \beta X + \varepsilon$$

Where; X is a vector of variables determining the discrete ordering for crash observation, β is a vector of estimable parameters, and ε is a random error term. Using the above equation, each injury outcome level (y) which are ordinary, can be represented as observable;

$y=1$ if $z \leq \mu_0$ (No injury)

$y=2$ if $\mu_0 < z \leq \mu_1$ (Injury)

$y=3$ if $\mu_1 < z \leq \mu_2$ (Fatal)

The crash data contain several variables used by the model to generate the study results. The model describes the severity of crashes in relation to other variables such as speeding, reckless driving, vehicle malfunction, day of the week, time of day, driver's age, and type of collision. Each variable is categorized as coded in the model.

Table 2 shows different variables in relation to crash severity. Speeding contributes more to fatal severity in the case of crash causes, with a total of 54%. Reckless driving and vehicle malfunction have a lesser contribution in comparison to speeding.

Speeding control devices reduced crash fatal severity by 22.2%. Before the introduction of the devices, the fatal

severity was 61.1%, and after their introduction, it was reduced to 38.9%. The same trend applies to other severity levels; before the introduction of the devices, severity levels were higher compared to after their introduction.

Collisions with pedestrians and motorcycles did not record a low level of severity (no injury). All the crashes in these categories resulted in injuries and fatalities. Pedestrians recorded more fatalities compared to other collision types, with a total of 33%.

Drivers of younger age recorded more severity at all levels compared to middle-aged and older drivers. For fatal severity, younger drivers recorded 39.5%. Crashes occurring during the daytime were more severe than those occurring at night, and more crashes occurred during the daytime compared to the nighttime.

In estimating the model, all variables were checked for correlation. One of the assumptions in developing the regression model is that there should be little or no multicollinearity among the independent variables. This means that the independent variables should not be too highly correlated with each other [19]. The study used the variance inflation factor (VIF) to check the correlation of variables. The variance inflation factor is used to detect multicollinearity in regression analysis. The correlation between variables estimates how much the variance of a regression coefficient is inflated due to multicollinearity. The software (R Studio) typically calculates this factor and provides a table of output [2].

Table 2. Shows different variable in relation to crash severity variable correlation explains how two variables are closely related

Attribute	Attribute Category	Injury Severity						Total
		No Injury		Injury		Fatality		
		Count	Percent	Count	Percent	Count	Percent	
Speeding	No	435	68.6	57	39.0	85	45.9	577
	Yes	199	31.4	89	61.0	100	54.1	388
Reckless driving	No	472	74.4	118	80.8	141	76.2	731
	Yes	162	25.6	28	19.2	44	23.8	234
Vehicle malfunctioning	No	553	87.2	139	95.2	174	94.1	866
	Yes	81	12.8	7	4.8	11	5.9	99
Speeding control device	Before 2018	384	60.6	91	62.3	113	61.1	588
	2018+	250	39.4	55	37.7	72	38.9	377
Day of the week	Weekday	466	73.5	100	68.5	125	67.6	691
	Weekend	168	26.5	46	31.5	60	32.4	274
Time of day	Daytime	583	92.0	126	86.3	167	90.3	876
	Nighttime	51	8.0	20	13.7	18	9.7	89
Bus driver age	<30	257	40.5	52	35.6	73	39.5	382
	30-40	195	30.8	44	30.1	54	29.2	293
	40+	182	28.7	50	34.2	58	31.4	290
Collision with	Passenger car	441	69.6	52	35.6	54	29.2	547
	Trucks	193	30.4	21	14.4	27	14.6	241
	Motorcycle		0.0	23	15.8	43	23.2	66
	Pedestrian		0.0	50	34.2	61	33.0	111

Table 3. Variable correlation

Parameters	GVIF	Df	GVIF ^{1/(2*Df)}
Speeding	1.81409	1	1.346881
Day of the week	1.011426	1	1.005697
Time of the day	1.051945	1	1.025644
Driver age	1.038426	2	1.009471
Driver gender	1.008147	1	1.004065
Reckless driving	1.695375	1	1.302066
Vehicle malfunction	1.278803	1	1.130842
Collision with	1.079925	3	1.012898
Speeding control device	1.007989	1	1.003986

4.3. Results and Discussion

The results of the model are discussed as displayed in Table 4. The table contains parameters that explain the results and findings of the study. Parameters are considered significant if the 90% confidence intervals are both of the same sign (either negative or positive) in the model result (i90% CI and u90% CI).

These parameters include severity, estimates, speeding, collision with variables, reckless driving, and time of the day. Severity is the response variable in the ordered logistic regression model. Severity was classified into three levels: no injury, injury, and fatal. 'No injury' severity means property damage only; 'injury' severity means the crash resulted in injuries; and 'fatal' severity means the crash resulted in deaths. The severity levels are the predictors in the cut points of all the variables.

Estimates are the ordered logit regression coefficients of the variables. These coefficients mean that for a one-unit increase in the predictors, the response variable level changes by its regression coefficient on the ordered logit scale, while other variables remain constant.

Speeding was coded in two parts: 'yes' and 'no.' 'Speeding1' represents 'yes,' indicating that severity was caused by speeding.

The ordered logit estimates for a one-unit increase in speeding causes the expected severity level to increase by 1.49, while other parameters remain constant. The severity level increases by 0.02 for crashes not caused by speeding. The parameter for crashes caused by speeding ('speeding1') was significant at the 90% confidence level, while 'speeding2' was not significant.

The 'Collision with' variable was coded in three parts: collision with a passenger car was coded as 'collision with 1,' collision with trucks was coded as 'collision with 2,' and collision with motorcycles and pedestrians was coded as 'collision with 3.' The ordered logit estimate indicates that the expected severity level increases by 0.08 for a one-unit increase in collision with a passenger car, while other parameters remain constant. The ordered logit estimates for a one-unit increase in collision with trucks causes the expected severity level to increase by 2.43, while other parameters remain constant. The ordered logit estimates for a one-unit increase in collision with motorcycles and pedestrians causes the expected severity level to increase by 2.19, while other parameters remain constant. Collision1 and collision2 are significant, while collision3 is not significant.

Reckless driving was coded as 'yes' and 'no.' For crashes caused by reckless driving, the ordered logit estimates for a one-unit increase in reckless driving causes the expected severity level to increase by 0.35, while other parameters remain constant. However, the parameter was not significant. Crashes not caused by reckless driving were coded as 'Reckless driving 2' and had a negative estimate with no significance.

Time of the day includes daytime and nighttime. Crashes that occurred during the day were coded as daytime (1), and those that occurred during the night were coded as nighttime (2). The ordered logit estimate indicates that more crashes occurred during the daytime, with an increase of 0.39 in severity level, but the parameter was not significant. Nighttime had a negative estimate, with the variable being significant at the 90% confidence interval (CI).

Table 4. Model Results

Severity	Estimate	Est. Error	l-90% CI	u-90% CI	Rhat	Bulk ESS	Tail ESS
Day of week	0.20	0.12	0.00	0.41	1	4755	3195
Collision with1	0.08	0.13	-0.14	0.29	1	3890	2730
Collision with2	2.43	0.23	2.05	2.81	1	4069	3212
Collision with3	2.19	0.17	1.91	2.49	1	3920	2951
Speeding control device	-0.01	0.11	-0.19	0.17	1	4757	3119
Speeding [1]	1.49	0.27	1.05	1.96	1	2389	2315
Speeding [2]	0.02	0.35	-0.55	0.62	1	2051	2577
Time of day [1]	0.39	0.31	-0.14	0.89	1	4008	2916
Time of day [2]	-0.99	0.41	-1.66	-0.31	1	4213	2483
Driver age [1]	-0.08	0.24	-0.47	0.31	1	2471	3068
Driver age [2]	-0.19	0.31	-0.70	0.31	1	3047	3073
Driver age [3]	0.19	0.24	-0.21	0.57	1	2954	2533
Reckless driving [1]	0.35	0.32	-0.17	0.86	1	2624	2892
Reckless driving [2]	-0.04	0.42	-0.72	0.65	1	2433	2834
Vehicle malfunction [1]	-0.37	0.48	-1.17	0.39	1	3097	3314
Vehicle malfunction [2]	-0.14	0.62	-1.15	0.87	1	2853	3070

5. Conclusions and Recommendations

5.1. Conclusions

Regional bus crashes show a difference between the years before and after the introduction of vehicle tracking devices. The findings of the study show that the number of crashes reduced after the introduction of the devices. The severity of bus crashes along the corridor is predominantly characterized by property damage. During the six-year period, a total of 633 crashes were classified as property damage. Both buses and highway facilities are affected when a crash occurs. As a result, regional buses in the corridor have led to fatalities, injuries, and damage to vehicles and highway facilities, such as signposts, light posts, and pavements.

Crash severity and occurrence have both reduced after the introduction of the vehicle tracking system. Mid-year and end-of-year periods have experienced more bus crashes, as these times coincide with holidays for schools, colleges, and universities, leading to higher regional movement of people. Between May and August, a total of 320 crashes occurred in the corridor between Dar es Salaam and Dodoma. In the period between September and December, there were 375 bus crashes in the corridor. This shows that the end-of-year period experiences more crashes involving regional buses in this corridor.

During the week, the study found that more regional bus crashes occurred on weekends. Saturdays and Sundays recorded a total of 275 crashes over the six-year period. Most regional bus crashes are caused by speeding and reckless driving, while environmental factors and vehicle malfunction contribute less. A total of 645 crashes were caused by speeding and reckless driving during the six-year period.

Reckless driving in this case involves drunk driving, rubbernecking, sleeping, cellphone use, and chatting with passengers. Human factors are the primary contributors to the majority of regional bus crashes.

Driver's age can influence crash severity and occurrence. Most young drivers under the age of 45 have been involved in more crashes compared to drivers above that age. Drivers in this age range typically feel energetic and sharp, which leads them to speed, ultimately resulting in more crashes. Drivers under 45 years old have been involved in a total of 520 crashes over a six-year period along the corridor from Dar es Salaam to Dodoma, causing 349 fatalities and injuries.

Driver's gender has an influence on crash occurrence. Over the past six years along the corridor, male drivers have been involved in more crashes compared to female drivers. The aggressiveness of male drivers on the road is one of the reasons they are involved in more crashes.

5.2. Recommendations

A critical analysis of the study found that the vehicle tracking system is effective in improving safety to some extent. The study provides the following recommendations to increase the safety effectiveness of the vehicle tracking system and reduce crashes involving regional buses and

other road users:

- Strict penalties for all drivers exceeding the posted speed limit detected by the system. Once a driver exceeds the speed limit, a heavy penalty should be issued to make drivers realize the consequences of speeding.
- Road signs should be clearly visible, and regular maintenance of highway facilities should be adopted to ensure drivers have a clear view of all signs and obstacles along the road.
- The vehicle tracking system should be able to detect areas with a high crash history and alert drivers or reduce the speed limit in those areas. The devices should be more digital so that sudden changes can be made and communicated to the driver.
- The study also recommends that clear education be provided to passengers so that, when on the road, they can take responsibility and talk to the driver if they hear an alarm from the system. Currently, if you travel on regional buses, you may hear the alarm when the driver exceeds the speed limit, but no passengers complain.

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