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Governmental Expenditures and the Challenges to Improve Road Safety in Brazil

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Abstract

This article addresses governmental actions to improve road safety through the analysis of road traffic fatalities and expenditures in education, engineering, and enforcement (the 3E's approach) in Brazil between 2011 and 2021 from the *Fundo Nacional de Segurança e Educação de Trânsito* (Funset), a public fund to support actions in safety, education, and engineering to improve Brazilian road safety. Graphical analysis was conducted, Pearson correlation coefficient was used for the variables of Funset expenditures (*lnpay*) and road deaths in Brazil (*lndeaths*), and a linear regression model was built to estimate the variation in road fatalities as a function of Funset expenditures. The results show a decrease in road deaths in Brazil with a slight upward trend and a reduction in Funset expenditures for road safety improvement. There is a positive correlation between the downward trend in Funset public investments in education, engineering, and enforcement and fatalities on roads of 0.79. Funset expenditures are inadequately allocated with low expenditure execution average (16.8%). There are many challenges for the Brazilian public administration to ensure road safety, however, it is important to maintain financial support for road safety strategies to improve it and save lives.

Keywords: road safety, road deaths, Funset, education, engineering, enforcement

1. Introduction

There is a growing concern about traffic, a topic of significant interest, due to accidents, which are a global public health issue, especially for low-income and middle-income countries (Wang & Chan, 2016). In Brazil, traffic accidents represent a severe social problem, placing the country among the top four globally for traffic-related deaths, according to the World Health Organization (WHO, 2019).

In March 2010, the United Nations General Assembly established the First Decade of Action

for Road Safety (2011-2020), during which signatory countries, including Brazil, were expected to develop actions to reduce traffic fatalities (WHO, 2019). Wanke et al. (2023) highlight that in 2021, the UN established the Second Decade of Action for Road Safety to set more ambitious goals for road safety until 2030.

For initiatives aimed at reducing traffic fatalities to achieve their objectives it is necessary to implement education, engineering, and legal enforcement measures or strategies. These measures form the foundation, or the three E's approach of road safety (Hezaveh et al., 2019).

Recent studies have involved at least one of the elements of the three E's of road safety in developing countries. For instance, Özen (2018) analyzes the trends of traffic crashes, deaths, and injuries in Turkey from 1980 to 2016. The author observed public investments in roads increased every year after 1995, traffic enforcement was strengthened, and the number of deaths and mortality rates significantly decreased, although they remained above the levels recorded in the European Union.

Sánchez-González et al. (2021) studied the influence of various factors, such as legislative changes and the quality of road infrastructure on the risks of mortality and injuries in rural road accidents in Chile from 2000 to 2017. Their results indicated that strengthened enforcement had a positive effect on reducing mortality and injury rates per vehicle. However, the estimates showed that the effectiveness of the investments made in Chilean roads did not meet expectations.

Specifically, regarding road safety in Brazil, Bacchieri and Barros (2011) in a literature review, describe the situation of traffic accidents in Brazil. They found that the main problems include the increase in the absolute number of deaths and mortality rates, the expansion of the motorcycle fleet, and alcohol abuse. They also indicated that public authorities have not assumed responsibility for controlling and reducing road accidents.

Abreu et al. (2018) analyzed the impact of the regulation of road accident mortality in a Brazilian state from 1980 to 2014. They found a reduction in road accident mortality rates shortly after the implementation of a national traffic law in 1998. However, mortality rates increased in the years following 2005. The Brazilian government structure for traffic is established through a national traffic system, where its agencies and entities prioritize actions to protect life (Rizzardo, 2004). To prioritize life protection, it is essential to adopt measures that strengthen road safety, promoting the 3E's of traffic safety (education, engineering, and enforcement).

Bassi (2019) explains that Brazil has adopted the creation of special financial funds, which are sets of financial resources aimed at specific purposes to enhance the effectiveness of certain public policies. In the case of Brazilian traffic policies, the *Fundo Nacional de Segurança e Educação de Trânsito* (Funset) was established to allocate resources for education, traffic engineering, and enforcement.

Based on that literature, this study has two hypotheses: (H_1) there is a negative correlation between public investment and the reduction of road fatalities, as investing public resources in the 3E's approach of road safety contributes to reducing road fatalities; (H_2) Funset's

expenditures are appropriately applied in education, traffic engineering, and enforcement, as it was created to improve road safety. This study aims to analyze public investments in government actions within the 3E's, providing a graphical and statistical description of variables and proposing a linear regression model, considering road fatalities in Brazil based on the Brazilian federal government's Funset expenditures.

Thus, this study has an objective beyond those of previous studies, which generally address trends related to accidents or deaths. This research aims to verify whether the implementation of government actions (through public resources allocation) contributes to increasing road safety (reducing roads mortality). It is expected to provide evidence on how public managers can direct public resources to road safety to mitigate road mortality and, thereby, contribute to making government actions more effective in addressing the severe problem of traffic-related deaths in Brazil.

2. Literature Review

Some works in the literature have already addressed the relationship between traffic safety and public investments in developing countries. Wanke et al. (2023) analyzed the trends in road accidents in Brazil and observed that the number of accidents has been decreasing over time. So, the initiatives under the 3E's approach rely on financial resources provided by public administration to improve road safety.

Yao et al. (2020) elucidate the relationship between the primary factors influencing traffic safety, highlighting the significance of the traffic safety investment ratio. They develop and implement an evaluation index system for urban road traffic safety to assess the traffic safety conditions in Wuhan, China. Their findings indicate that the traffic safety investment ratio significantly contributes to enhancing traffic safety. However, the results of the constructed model reveal that, in the assessed city, the safety level is moderate and requires improvement.

To analyze the impact of certain factors on road traffic fatalities in China from 2004 to 2016, Sun et al. (2019) investigated the relationship between highway accidents and five factors, one of which was traffic investments, using a panel model. They concluded that an increase of 100 million Chinese *yuans* in traffic investment reduced accidents in the country by 13.93, improving road safety.

For the study by Petrov and Petrova (2018), the results of research on the heterogeneity of accident rates in Russian cities from 2015-2016 were used. They considered five classes of Russian cities based on their level of road traffic safety (unacceptably low, low, medium, high, and very high). They then suggested different investments in road traffic safety programs for different Russian cities, taking into account each city’s road traffic safety class. To improve road traffic safety, it is suggested that cities with an unacceptably low level of road traffic safety should invest 1% of their budget in road traffic safety programs, whereas cities with a very high level should invest 0.2% of their budget (five times less).

Özen (2018) analyzed data from 1980 to 2016 regarding the relationship between road safety investments and traffic enforcement on traffic crashes, deaths, and injuries in Turkey. It was observed that starting from 1995, when a larger budget was allocated to road safety, deaths

decreased by 43% from 1998 onwards. Furthermore, actions in road investments combined with stricter enforcement measures can reduce the number of accidents and fatalities.

All the studies cited share the common finding that increasing investments in road safety has the potential to reduce traffic accidents and fatalities.

2.1 Initial Concepts

According to the Brazilian law, traffic is defined as "the use of roads by people, vehicles, and animals, either alone or in groups, whether driven or not, for the purposes of circulation, stopping, parking, and loading or unloading operations" (Rizzardo, 2004), involving various elements, especially the movement of vehicles, people, and animals on the roads.

Safe traffic encompasses the research efforts in developing road safety theory and the factors affecting road safety, such as those related to traffic characteristics, road users, and the environment (Wang et al., 2013). Road safety aims to reduce the risk of road accidents and provide a safe environment through actions in education, engineering, and enforcement, as stated by Maqbool and Singh (2019).

Safe traffic depends on what Hamim et al. (2020) and Guidoni et al. (2020) refer to as the traditional approach to road safety or the 3E's approach, which involves actions in engineering, education, and legal efforts for road safety.

The integration of educational, engineering, and legal measures makes road safety possible. Educational strategies are crucial for developing safe behaviors, particularly regarding educational campaigns to raise public awareness about traffic rules, driving norms, information on safe walking, and the importance of caring for others, as stated by Dunckel et al. (2014).

Moreover, the use of engineering techniques in constructing sidewalks and pedestrian signals at intersections makes the physical environment safer, according to Dunckel et al. (2014). Regarding legal efforts, the study by Thomas et al. (2008) demonstrates the effectiveness of enforcement and patrolling programs. There was also a high compliance rate with traffic laws following the implementation of automated camera technologies at traffic lights and speed radar to complement traditional enforcement activities (Dunckel et al., 2014).

2.2 Education

The promotion of traffic education aims to encourage road users to adopt safe behaviors, as conscientious pedestrians and drivers certainly reduce the risk of road accidents. Road safety highly depends on the behavior of its users (Dunckel et al., 2014).

Brazilian law broadly addresses education for traffic safety, as education plays an essential role in improving road safety measures, according to Hung and Huyen (2011). Traffic education aims to influence people's mindsets by imparting knowledge about traffic regulations to raise awareness among users about the fight to reduce road violence.

Education impacts individuals by shaping behaviors for the incorporation of safe habits through an uninterrupted and systematic process of awareness. Traffic education should not

be based solely on the knowledge, understanding, and respect of traffic rules but should also promote understanding and respect for the principles underlying these rules (Macedo & Souza, 2020), fostering actions that result in harmonious coexistence on the roads.

Traffic education seeks to guide road users on appropriate behavior to preserve life and physical integrity, as well as to form responsible citizens aware of their rights and obligations in traffic (Honorato, 2011).

Various strategies can be employed in this field, such as advertisements, educational programs in schools, and traffic safety exhibitions, to encourage compliance with regulations or reduce accidents. For example, Dunckel et al. (2014) demonstrated a decrease in accidents and fatalities following the adoption of educational measures and other initiatives in a county in Tennessee, USA. Additionally, the research by Hung and Huyen (2011) analyzed two educational policies for traffic law compliance in Vietnam, finding that the first policy resulted in a high percentage of drivers adhering to the rules even after the campaign ended, whereas the second one showed that most drivers complied only during the campaign's duration.

Although necessary, educational campaigns may have a reduced long-term effect on user behavior (Hung & Huyen, 2011), especially if they are conducted sporadically and without coordination. Therefore, it is crucial to have a source of public funding to finance and coordinate these educational actions.

2.3 Traffic Engineering

Traffic Engineering applies engineering principles to solve transportation-related problems and deals with the planning, design of streets, traffic control, speed limits based on road characteristics, vehicle safety equipment and measures, technical accident analysis, among others, to enable mobility under good conditions (Guidoni et al., 2020). Traffic Engineering is related to the planning, operation, and utilization of roadways with the aim of providing transportation with maximum safety, efficiency, comfort, fluidity, and accessibility.

Engineering interventions ensure the development of road planning, traffic management (operational strategies), infrastructure projects (construction of roads, overpasses, bridges, traffic devices, etc.), circulation and parking (defining road hierarchies, travel directions, parking locations, and operational methods at intersections with or without traffic lights), and the implementation of traffic signaling (McIlroy et al., 2019).

Traffic engineering promotes road safety. In this regard, Sinay and Tamayo (2005) argue that it is employed to mitigate accident risks by implementing rational actions to enable proper circulation patterns. Traffic engineering is greatly concerned with road safety as it relates to safe circulation, accident prevention, and reducing traffic mortality. By applying appropriate engineering intervention techniques combined with traffic operation, it is possible to achieve satisfactory results in reducing traffic violence.

Consequently, there are many ways to engineering improve road safety, enabling the development of various projects aimed at achieving optimal road safety conditions (Hamim et

al., 2020). Engineering interventions has great importance and can be applied to critical points susceptible to traffic accidents, potentially reducing or even eliminating accidents at the intervention site, thereby ensuring greater safety for road users.

2.4 Enforcement

Enforcement refers to the enhancement of legal norms and the utilization of the law to shape driver behavior (McIlroy et al., 2019). It seeks to ensure that traffic safety regulations are applied and obeyed. Its relation to road safety occurs because it is a key element in controlling traffic violations by deterring drivers' irregular behaviors, as pointed out by Hung and Huyen (2011).

For Maqbool and Singh (2019), enforcement can reduce the number of road accidents and deaths because legislation could be an effective tool to discourage risky behaviors and improve road safety through a set of regulations governing traffic and the practical implementation of legislation.

Enforcement prioritizes the transformation or prevention of improper behaviors by drivers and pedestrians through the promotion of positive attitudes or the coercion and application of sanctions for behaviors that infringe upon traffic laws and other regulations (Chaves, 2024).

The effective and efficient promotion of legal efforts, notably based on legislation, allows for the utilization of human, technological, and computerized management system resources, especially focused on traffic violations and risk factors that may result in road accidents and deaths. Thus, by enforcing legislation and conducting road enforcement, the aim is to strengthen road safety through the repression of traffic violations, especially those with the potential to cause traffic accidents, injuries, and fatalities (Hamim et al., 2020).

2.5 Special public Funds and the Funset

In Brazil, a special public fund is a set of specified public revenues intended for achieving certain objectives to effectively manage decentralized financial resources to meet established purposes through appropriations provided in the budget law (Sanches, 2002). It is widely accepted by sectoral managers in public administration for allocating resources to specific purposes (Giacomoni, 2019).

In 1998 was established the *Fundo Nacional de Segurança e Educação no Trânsito* (Funset), it something like National Traffic Safety and Education Fund, a public fund to support actions in safety, education, and engineering to improve Brazilian road safety which aims to cover the expenditures of the Brazilian federal government related to road safety, education, and engineering, and is the main source of funding for promoting road safety on Brazilian roads (Carvalho & Guedes, 2023).

Revenue from traffic fines is exclusively allocated to traffic signaling, traffic engineering, patrolling, enforcement, and traffic education, with five percent of this amount allocated to the Funset (Rizzardo, 2004). Through this public fund, budgetary actions are carried out to implement measures for road safety, and for the execution of actions through a special public fund, expenditures are incurred (Giacomoni, 2019).

3. Methods and Results

This study presents discussions on government actions in education, engineering, and legal efforts, with an emphasis on the Funset budget, to improve road safety. In this way, the aim is to analyze the implementation of financial resources used to improve road safety on Brazilian roads.

The adopted method consists of verifying the correlation and analyzing government performance from the perspective of two variables: payment of Funset expenditures, as this demonstrates the execution of purchases or provision of public services (Giacomoni, 2019), and examination the promotion of traffic safety by comparing government expenditures from the Funset in education, engineering, and enforcement with traffic road deaths in Brazil.

The correlation between the variables in the natural logarithm form of expense payments (*lnpay*) and road deaths in Brazil (*lndeaths*) will be conducted using the Pearson correlation coefficient. The estimation of the traffic mortality function will be based on a linear regression model with the following equation:

$$Yi = \beta_1.X_{1i} + \beta_2.X_{2i} + \varepsilon_i \quad (1)$$

Where:

Yi = natural logarithm of traffic deaths (*lndeaths*);

X_{2i} = natural logarithm of Funset expenditures paid in millions of Brazilian reais (*lnpay*);

β_1 = Intercept or linear coefficient;

β_2 = Slope coefficient;

ε_i = Error term for factors not explicitly stated in the model.

Additionally, a graphical and descriptive analysis of Funset payment execution will be conducted to verify if public funds are being appropriately allocated to reduce traffic mortality. Proper allocation of resources is understood as directing the majority of funds towards the purposes of the Funset (education, engineering, and enforcement).

3.1 Testing Hypotheses

3.1.1 Negative Correlation between Public Investment and the Reduction of Road Deaths

The correlation between the variables *lndeaths* and *lnpay* corresponds to the coefficient that measures the intensity and direction of linear relationships between them. Through Pearson correlation, we have the result:

Table 1. Pearson Correlation Coefficient for *lndeaths* and *lnpay*

Variable	*lnpay*
lndeaths	0.79

The correlation intensity is strong and positive, reaching nearly 0.8. A positive correlation indicates that high values of one variable correspond to high values of the other variable. The graphical analysis of traffic deaths and Funset expenditures paid in logarithmic form, along with the percentage of budget execution, is obtained through Figure 2:

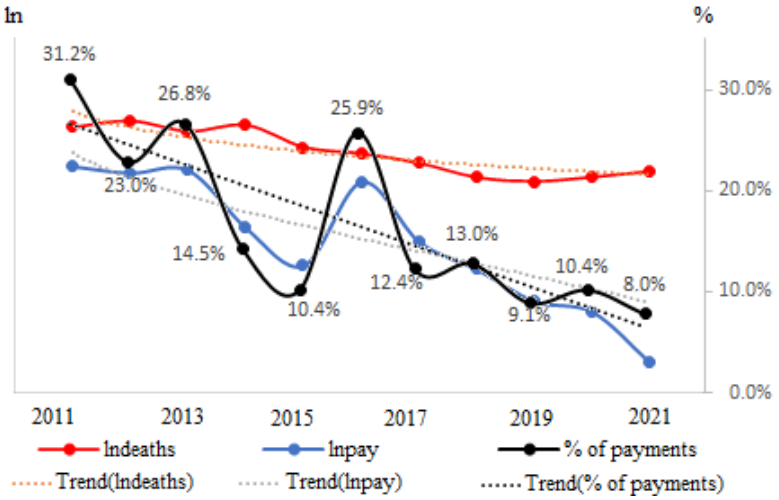

Figure 1. Road accident deaths (ln), Funset paid expenditures (ln), and Funset payment percentage

The graphical analysis of the variables *lndeaths* and *lnpay* confirms the initial downward trend, but shows some stability towards the end of the period. The percentage of expenditures executed, which corresponds to the ratio between authorized expenditures and those actually paid to suppliers or service providers, bears some resemblance to the last variable, indicating the similarity in the behavior of available resources volume and the actual payment of expenditures.

3.1.2 Proper Allocation of Funset Resources

Regarding this research, the following variables related to traffic are analyzed: annual road accident fatalities in Brazil and annual payments of Funset expenditures, assuming that investments in education, engineering, and legal efforts contribute to traffic safety and tend to reduce the number of fatalities.

In Table 2 there is a description of traffic deaths, Funset expenditures, and their budget execution per year as follows:

Table 2. Traffic fatalities and Funset expenditures

Year	Road deaths [1]	Funset expenditures [2](milhões de R$)		Funset expenditures execution [3](%)
		Authorized	Paid	
2011	43 256	1 308.22	407.52	31.2
2012	44 812	1 655.77	380.71	23.0
2013	42 266	1 459.82	391.02	26.8
2014	43 780	1 486.66	216.18	14.5
2015	38 651	1.415.54	147.3	10.4
2016	37 345	1 342.93	347.48	25.9
2017	35 375	1 509.06	187.68	12.4
2018	32 655	1 090.05	141.34	13.0
2019	31 945	1 117.25	101.88	9.1
2020	32 716	876.31	91.32	10.4
2021	33 813	679.45	54.22	8.0
Average	**37 874**	**1 252.55**	**224.24**	**16.8**

[1]Road accident deaths in Brazil. Data from Statistics portal from *Observatório Nacional de Segurança Viária*, 2023. From: http://iris.onsv.org.br/portaldados/#/

[2]Values in millions of Brazilian *reais* (R$) adjusted by Brazilian inflation index (IPCA) at May 2022 prices. Data from *Confederação Nacional dos Transportes* (CNT). In: Educação e segurança de trânsito: os recursos do Funset têm sido efetivamente aplicados nas suas finalidades. Brasília, 2022.

[3]Ratio between paid and authorized expenditures. Data from CNT. *Idem*.

In Table 2, we observe an average of 37 584 fatalities with a gradual reduction in deaths year after year. Authorized expenditures show a declining trend, which by the end of the period, were reduced to almost half, and as for those paid, they are also decreasing, reduced to about 13% of the initial expenditures amount. The percentage of Funset expense execution is

noteworthy, as in 2011, less than a third of the resources were executed, and in the last period, only 8% of the expenditures from the mentioned public fund were executed, which is less than half of the average execution for the period. Therefore, the allocation of public resources in education, engineering, and enforcement is low, with an average for the analyzed period below 20%.

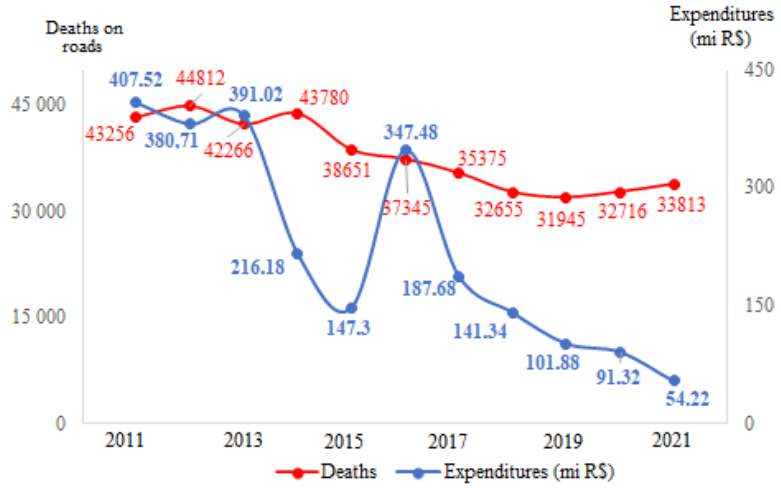

Figure 2. Road accident deaths versus and payment of Funset expenditures

Figure 2 demonstrates the evolution of road fatalities, which was reduced from about 43 000 at the beginning of the series to close to 33 000 at its end. Although there were alternations between increases and decreases in the first four years, there was a considerable decrease in deaths between 2014 and 2019. However, in 2020 and 2021, moderate increases are recorded.

For Funset expenditures payments, there was little variation in the first three years, followed by a sharp reduction between 2013 and 2015. Exceptionally, in 2016, there was a noticeable increase in paid expenditures, and since then, there have been successive declines until the amount of just over R$ 54 million in 2021, the lowest recorded and far below the amounts paid in 2013. There is a trend of decreasing public resource allocation to road safety, as well as a decrease in mortality between 2011 and 2021.

Based on the proposed methodology, Table 3 describes the linear regression model for the annual periods from 2011 to 2021 with the corresponding dependent variable for *lndeaths* as a function of *lnpay*, as follows:

Table 3. Multiple regression estimates (*lndeaths* and *lnpay* between 2011 and 2021)

Variable	Parameter	Estimated coefficient	T Statistic	P-value
Intecept	β_1	9.740473*	47.74	0.000
Paid expenditures (*lnpay*)	β_2	0.1519803*	3.92	0.004
Dependent variable:Road accident deaths (ln)				
R^2:	0.6307			
Adjusted R^2:	0.5897			
F test:	0.0035			
Durbin-Watson:	1.141235			

* Statistical significance at the 1% level.

R^2: Coefficient of determination.

Adjusted R^2: Adjusted Coefficient of determination.

The intercept holds significant importance, given the t-statistic value of 47.74 and a coefficient of 9.74. The coefficient $\beta 2$ carries less weight with a t-statistic test value of 3.92 and indicates that, in the analyzed series, a decrease of 0.15% in Funset paid expenditures results in a 1% reduction in the number of traffic accident deaths. Therefore, it establishes the direct relationship between the decrease in the values of the variables over the period.

The coefficient of determination (R^2) of 0.6307 reveals that the independent variable *lnpay* accounts for approximately 63% of the variation in *lndeaths*. The F-test with a value of 0.0035 indicates statistical significance at the 1% level, thus, the estimated parameters $\beta 1$ and $\beta 2$ are statistically different from zero. However, the value of the Durbin-Watson statistic, at 1.141235, suggests the presence of serial autocorrelation among the residuals, which may indicate a spurious regression. In this phenomenon, even if high and significant correlation is detected, the model may not make sense (Gujarati & Porter, 2009). Therefore, a unit root test is conducted to check the stationarity of the series.

Table 4. Augmented Dickey-Fuller Unit Root Test Results

Variable	p-value
lndeaths	0.8090
lnpay	0.9014

The results of the tests in Table 4 show that the probabilities of non-stationarity for *lndeaths*

are over 80% and over 90% for *lnpay*. The Engle-Granger co-integration test was conducted with values pertaining to the variation of lagged residuals, and thus, the following results were obtained:

Table 5. Estimates for the Engle-Granger co-integration and regression test

Variable	Parameter	Estimated coefficient	T Statistic	P-value
Intecept	β_1	9.601025*	112.19	0.000
Paid expenditures (*lnpay*)	β_2	0. 1784119*	10.81	0.000
Lagged residuals	β_3	1.059187*	7.39	0.000
Dependent variable:	Road accident deaths (ln)			

* Statistical significance at the 1% level.

Table 5 presents estimates very close to those in Table 3. The t-statistic values showed significant changes, increasing the weight of the intercept in the model, but the same thing occurs with *lnpay*. The estimated coefficient values were adjusted to slightly lower for the intercept and slightly higher for *lnpay* as per the linear regression model in Table 2. According to Table 4, the variables *lndeaths* and *lnpay* are cointegrated, or there is long-term equilibrium between them, thereby correcting any distortions presented in the initial regression.

The estimated model assuming logarithmic variables represents an elasticity relationship, with statistically significant estimated parameters at a 1% level with positive signs, revealing the direct relationship between the variables. It should be noted that the interpretation of the model does not imply the influence of Funset expenditures on the number of traffic deaths but rather captures the trend of reduction in both variables over the period, as academic literature points to an inverse relationship between the two variables analyzed.

In this scenario, there is a general reduction in the number of traffic deaths, with a trend of some increase towards the end of the observed period, accompanied by a steep decrease in public resources allocated to payment for road safety actions.

4. Discussion

This study analyzes public investments according to the 3E's approach for road safety (education, engineering, and enforcement) and road fatalities in Brazil from 2011 to 2021.

Two hypotheses were posited: (H_1) there is a negative correlation between public investment and the reduction of traffic deaths; (H_2) Funset expenditures are adequately allocated to education, traffic engineering, and enforcement. The results indicate a positive correlation between the reduction of Funset public investments in education, engineering, and enforcement and deaths on roads in Brazil between 2011 and 2021 of 0.79.

There were low investments from Funset in road safety. Resource allocation averaged 16.8%. In the last 3 years analyzed (2019 to 2021), applied resources were around 10% of the total, which is a concerning finding as public funds are being allocated to other purposes.

Previous studies indicate a negative relationship between road safety investments and fatalities. Özen (2018) observed decreasing trends in accidents, injuries, and deaths with increased road investments in Turkey, indicating an inverse relationship. Similarly, Sun et al. (2019), analyzing road safety in Chinese provinces, found that increased road safety investments reduced fatalities, while Bacchieri and Barros (2011) added that the reduction in accidents in Brazil is also related to increased investments in road safety (data from a previous period).

However, the positive correlation found may be explained by the widespread trend of reducing Funset investments and road accident deaths according to Figures 1 and 2. Although academic literature points to a reduction in accidents and fatalities with increased road safety investments, this study found that in Brazil between 2011 and 2021, the reduction in deaths on roads was not accompanied by an expansion of application of public resources in 3E's approach strategies. Factors not addressed in the study, such as the incorporation of new vehicle technologies, may have contributed to the decrease in fatalities, as well as the prioritization of other areas of governmental action may explain the low execution of Funset expenditures.

Wanke et al. (2023) observed that the number of accidents decreased over time despite the absence of significant investments in infrastructure associated with other engineering and enforcement factors. Symons et al. (2019) point out the positive effects of costs in road safety interventions for reducing accidents and deaths. In an exclusive analysis of road costs, Calvo-Poyo et al. (2020) concluded that expenditures on road maintenance and conservation contribute to reducing road mortality.

Adequate investments from Funset in road safety were not supported by the findings because, unlike the findings of previous studies, in Brazil, these public resources were allocated to other areas. Thus, with the results presented, H_1 cannot be refuted because only the correlation between the decreasing trend in deaths and road safety resources over the years was demonstrated. The majority of literature evidences that increased spending on education, engineering, and enforcement becomes road traffic safer. The H_2 is refuted by the findings because adequate allocation involves a high percentage of resource execution, which did not occur during the analyzed period, indicating difficulties in managing public resources in road safety by the Brazilian government.

The decreasing number of road deaths in Brazil between 2011 and 2021 was accompanied by

a constant reduction in the volumes allocated to Funset expense payments, as estimated by the regression model.

This must be a warning to authorities to allocate resources to road safety to reduce the number of road deaths, especially since public resources fund education, engineering, and enforcement actions, which contribute to reducing fatalities. This is a crucial alert for public officials in low- and middle-income countries, especially in Brazil.

5. Conclusion

This study deals with public investment in governmental actions in education, engineering, and enforcement through Funset to improve road safety. Two hypotheses were established: (H_1) there is a negative correlation between public investment and the reduction of traffic deaths; (H_2) Funset expenditures are adequately allocated to education, traffic engineering, and enforcement. With the showed results, there was captured the downward trend in road deaths in Brazil and in Funset resources application, so H_1 cannot be refuted, especially since the literature reinforces an inverse relationship between road mortality and safety investments.

The Brazilian public administration uses public policies to ensure road safety, with the mobilization of financial resources that fund actions in education, engineering and enforcement carried out by Funset. The systematic implementation of actions in education, engineering, and enforcement contributes to preserving lives and reducing accidents and injuries.

Road deaths are a variable that highlights road safety conditions. Although there has been a decrease in the number of deaths in traffic accidents in Brazil between 2011 and 2021, by almost 25%, it is noted that in the last two years of this series there is a moderate increase in mortality, which reduces the overall effect of the decrease.

It was noticed that in Brazil there was a decrease in traffic deaths with a slight upward trend towards the end of the series and, more significantly, a sharp decline in the payment of expenditures from the Funset. There is also a significant reduction in the execution of financial resources from Funset.

There are several challenges to improve road safety, such as the decrease in Funset resources, an increasingly lower percentage of execution of its financial resources, and the allocation of resources from this area for other purposes, which demonstrate a possible decrease in the prioritization of traffic policies. To overcome such facts, efforts are needed to ensure investments in the areas of education, engineering, and enforcement, and Funset plays an important role in support the governmental actions in 3E’s approach, and implies, in practice, investment in strengthening road safety and increasing citizens' mobility.

Finally, it is emphasized that integrated measures of education, engineering, and enforcement are fundamental for the efficiency, and effectiveness of governmental actions in road safety. To achieve this paradigm, governmental action is fundamental for the adequate allocation of resources from Funset, in addition to the use of analysis tools, such as linear regression, in

accordance with evidence-based public policy strengthening management, in order to overcome the difficulties presented in the realization of its actions, so that road safety is improved.

References

Abreu, D. R. D. O. M., Souza, E. M. D., & Mathias, T. A. D. F. (2018). Impact of the brazilian traffic code and the law against drinking and driving on mortality from motor vehicle accidents. *Cadernos de Saude Publica*, *34*, e00122117. https://doi.org/10.1590/0102-311x00122117

Bacchieri, G., & Barros, A. J. (2011). Traffic accidents in Brazil from 1998 to 2010: many changes and few effects. *Revista de Saúde Pública*, *45*, 949-963. https://doi.org/10.1590/s0034-89102011005000069

Bassi, C. D. M. (2019). Fundos especiais e políticas públicas: uma discussão sobre a fragilização do mecanismo de financiamento (No. 2458). *Texto para Discussão*. https://repositorio.ipea.gov.br/bitstream/11058/9088/1/TD_2458.pdf

Calvo-Poyo, F., Navarro-Moreno, J., & de Oña, J. (2020). Road investment and traffic safety: An international study. *Sustainability*, *12*(16), 6332. https://doi.org/10.3390/su12166332

Carvalho, C. H. R. D., & Guedes, E. P. (2023). *Balanço da primeira década de ação pela segurança no trânsito no Brasil e perspectivas para a segunda década*. Transportes: Relatórios de Atividades/Técnicos. IPEA. https://repositorio.ipea.gov.br/bitstream/11058/12250/4/NT_42_Dirur_Balanco.pdf

Chaves, G. V. D. (2024). A fiscalização e a operação de trânsito: perspectivas para o direito ao trânsito seguro. *Revista JRG de Estudos Acadêmicos*, *7*(14), e141066. https://doi.org/10.55892/jrg.v7i14.1066

Dunckel, J., Haynes, W., Conklin, J., Sharp, S., & Cohen, A. (2014). Pedestrian safety initiative in Montgomery County, Maryland: Data-driven approach to coordinating engineering, education, and enforcement. *Transportation Research Record*, *2464*(1), 100-108. https://doi.org/10.3141/2464-13

Giacomoni, J. (2019). *Orçamento público*. São Paulo: Atlas.

Guidoni, D. L., Maia, G., Souza, F. S., Villas, L. A., & Loureiro, A. A. (2020). Vehicular traffic management based on traffic engineering for vehicular ad hoc networks. *IEEE Access*, *8*, 45167-45183. DOI:10.1109/ACCESS.2020.2978700

Gujarati, D. N., & Porter, D. C. (2009). *Basic econometrics*. McGraw-hill.

Hamim, O. F., Hoque, M. S., McIlroy, R. C., Plant, K. L., & Stanton, N. A. (2020). A sociotechnical approach to accident analysis in a low-income setting: Using Accimaps to guide road safety recommendations in Bangladesh. *Safety science*, *124*, 104589. https://doi.org/10.1016/j.ssci.2019.104589

Hezaveh, A. M., Nordfjærn, T., Everett, J., & Cherry, C. R. (2019). The correlation between education, engineering, enforcement, and self-reported seat belt use in Tennessee: Incorporating heterogeneity and time of day effects. *Transportation research part F: traffic psychology and behaviour*, *66*, 379-392. https://doi.org/10.1016/j.trf.2019.09.003

Honorato, C. M. (2011). Trânsito seguro: direito fundamental de segunda dimensão. *Revista*

dos Tribunais, 911, 107-169.

Hung, K. V., & Huyen, L. T. (2011). Education influence in traffic safety: A case study in Vietnam. *IATSS research, 34*(2), 87-93. https://doi.org/10.1016/j.iatssr.2011.01.004

Macedo, A. P. B., & Souza, P. R. P. (2020). Educação para o trânsito: um estudo sobre o comportamento humano. *Brazilian Journal of Development, 6*(7), 44548-44566. https://doi.org/10.34117/bjdv6n7-176

McIlroy, R. C., Plant, K. A., Hoque, M. S., Wu, J., Kokwaro, G. O., Nam, V. H., & Stanton, N. A. (2019). Who is responsible for global road safety? A cross-cultural comparison of Actor Maps. *Accident Analysis & Prevention, 122*, 8-18. https://doi.org/10.1016/j.aap.2018.09.011

Maqbool, Y., Sethi, A., & Singh, J. (2019). Road safety and road accidents: an insight. *International Journal of Information and Computing Science, Volume, 6*, 93-105.

Özen, M. (2018). Trends in road traffic crashes in Turkey, 1980-2016. *Niğde Ömer Halisdemir Üniversitesi Mühendislik Bilimleri Dergisi, 7*(2), 732-740. https://doi.org/10.28948/ngumuh.444765

Petrov, A., & Petrova, D. (2018). Classification of Russian cities by levels of road traffic safety: specifics of required management decisions. In 2017 International Science Conference on Business Technologies for Sustainable Urban Development, SPbWOSCE 2017 (Vol. 170). EDP Sciences. https://doi.org/10.1051/matecconf/201817005009

Rizzardo, A. (2004). *Comentários ao código de trânsito brasileiro*. São Paulo: Editora Revista dos Tribunais.

Sanches, O. M. (2002). Fundos federais: origens, evolução e situação atual na administração federal. *Revista de Administração Pública, 36*(4), 627-a.

Sánchez-González, M. P., Tejada-Ponce, Á., Bonnefoy, J., & Escribano-Sotos, F. (2021). Regional conditions and road traffic collisions on rural roads in Chile. *Journal of Transport & Health, 20*, 100996. https://doi.org/10.1016/j.jth.2020.100996

Sinay, M. C. F., & Tamayo, A. S. (2005). Segurança viária: uma visão sistêmica. *Artigo Cientfico. In: Rio de Transportes III. Rio de Janeiro, RJ*.

Sun, L. L., Liu, D., Chen, T., & He, M. T. (2019). Road traffic safety: An analysis of the cross-effects of economic, road and population factors. *Chinese journal of traumatology, 22*(05), 290-295.

Symons, J., Howard, E., Sweeny, K., Kumnick, M., & Sheehan, P. (2019). Reduced road traffic injuries for young people: a preliminary investment analysis. *Journal of Adolescent Health, 65*(1), S34-S43. https://doi.org/10.1016/j.jadohealth.2019.01.009

Thomas, F. D., Blomberg, R. D., Peck, R. C., Cosgrove, L. A., & Salzberg, P. M. (2008). Evaluation of a high visibility enforcement project focused on passenger vehicles interacting with commercial vehicles. *Journal of Safety Research, 39*(5), 459-468. https://doi.org/10.1016/j.jsr.2008.07.004

Wang, C., Quddus, M. A., & Ison, S. G. (2013). The effect of traffic and road characteristics on road safety: A review and future research direction. *Safety science, 57*, 264-275. https://doi.org/10.1016/j.ssci.2013.02.012

Wang, C. W., & Chan, C. L. (2016). Estimated trends and patterns of road traffic fatalities in

China, 2002–2012. *Traffic injury prevention, 17*(2), 164-169. https://doi.org/10.1080/15389588.2015.1045501

Wanke, P., Gil-Alana, L. A., & Tan, Y. (2023). Trends in road accidents on Brazil's highways: Evidence of persistence using fractional integration. *PLoS one, 18*(7), e0287302. https://doi.org/10.1371%2Fjournal.pone.0287302

World Health Organization – WHO. (2019). *Global status report on road safety 2018*. World Health Organization.

Yao, L. S., Song, Y., & Dan, L. (2020). Risk assessment research of urban road traffic safety based on Extension Matter Element Model. *Journal of Physics: Conference Series* (Vol. 1486, No. 7, p. 072020). IOP Publishing. http://dx.doi.org/10.1088/1742-6596/1486/7/072020

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