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Effects of Road Improvement on Road User Costs and Safety of Road Users: The Case of Outer Ring Road, Nairobi, Kenya

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Abstract

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Purpose: This study aimed to investigate whether road improvements promote the safety of road users as well as reduce the costs of road users. The study used the case of Outer Ring Road, Nairobi owing to its large traffic base, high incidence of accidents and having received a major facelift in recent years.

Methodology: The study used a non-experimental research design. Secondary data was collected for 2012 before road improvement began and in 2020 after road improvement. Data processing was done using SPSS software. This means for the study variables before road improvement and after road improvement was generated. The difference in difference (DID) was used for comparing baseline data collected in 2012 and endline data after project implementation as of 2020. This was done with the help of a t-test, ANOVA Test and the Difference in Difference Test. The multivariate linear estimation was to test for significance between the road improvements and the road user costs in 2012 compared to 2020.

Results: With a focus on safety of road users along the road, the median number of fatalities before road improvement on Outer Ring Road (2012) were 3 fatalities which later reduced to 1 fatality in after road improvement 2020. The median number of severe/ serious injuries before road improvement on Outer Ring Road (2012) were 9 injuries which later reduced to 4 injuries in after road improvement 2020. Likewise, owing to the effects of road improvement on Outer Ring Road, the median number of road accidents reduced from 22.12 in 2012 to 15.83 accidents in 2020. Likewise, with regard to road user costs, the median total travel time before road improvement on Outer Ring Road (2012) was 3.77 hours and later reduced to 0.041 hours in after road improvement 2020. The median costs of severe/serious accidents before road improvement on Outer Ring Road (2012) was KES 9.22 billion which later reduced to KES 4.41 billion in after road improvement 2020. Likewise, owing to the effects of road improvement on Outer Ring Road, the median costs of fatalities reduced from KES 2.52 billion in 2012 to KES 1.80 billion in 2020. Therefore, the study based on the above findings concludes that there is a significant interaction between the road improvements along Outer Ring Road, and the safety of road users (mean cost of fatality) in 2012 compared to 2020. Likewise, there is a significant interaction between the road improvements along Outer Ring Road, and the road user costs (mean total time travelled) in 2012 compared to 2020.

Unique contribution to theory, policy and practice: The study suggests the road agencies to improve the fixing road signs, road markings and enforcements of traffic rules to improve in the road safety performance. The study also recommends the road agencies to enhance expenditure on road repair and conservation in order to improve road safety and reduce excessive fatality rates. This will ensure the awareness of road users on the matters regarding safety of road usage like proper use of traffic lights, switching of lanes, speed limits etc., which could have an effect on the evaluations of road users and road user costs. These study findings will be useful to the future studies for system-based initiatives and may advise government legislation on human or human-environmental interacting aspects to optimize county-level and national-level road safety.

Keywords: *Road Improvements, Safety of road users, Costs of road users, Outer Ring Road*

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1.0 INTRODUCTION

1.1 Background of the study

1.1.1 Perspectives on Road Improvements in Kenya

The upgrade and construction of new roads contribute both positively and negatively to the environment and the general populace (Mackett & Edwards, 1998). What determines whether such impacts are negative, positive or both is the environmental, economic and social context in which they are viewed (Khanani, et al., 2021). The Global South has experienced increased popularity because of such development projects and also large-scale spatial planning. Further, the projects have resulted in other benefits for the economy such as the attraction of investors due to the improved connectivity and increased competitiveness. Infrastructural developments can enhance access to jobs and social facilities and improve mobility and the market for farm produce and services (Gibson & Rozelle, 2003; Pradhan & Bagchi, 2013).

In Kenya, road improvements have contributed to economic growth and social development through improvement in access to services, increased trade, urbanization, more employment opportunities, reduction in travel time and regional integration (Farooq et al., 2018; Omondi, 2014). Nationally, the Ministry of Transport develops policy and also implements projects relating to urban development, roads, rail, aviation, and housing among others. Both the Kenya Roads Act, 2007 and the Sessional Paper No. 5 of 2006 on the Development and Management of the Road Sub-Sector for Sustainable Economic Growth provide an anchor for road construction projects and infrastructure. The economic blueprint of Vision 2030 also spells out these plans under the economic, social and political pillars (the Republic of Kenya, 2012). Because effective and efficient infrastructure is an enabler for other sectors envisaged in the Kenyan Vision 2030, the Kenyan government has taken milestones to develop it (Republic of Kenya, 2018).

The implementation of Vision 2030 is done in five phases referred to as medium-term plans (MTPs). Currently, we are in the third phase (2018-2022) of the medium-term plans which now succeeds the second and third phases carried out in (2013-2017) and (2008-2012) respectively. The implementation of the third phase is done through policies and programmes under the county governments. To achieve the Big Four agenda, it is important to invest in infrastructural projects ranging from energy, air, road, rail, marine and ICT. During the first and second MTPs, the government implemented several projects and programmes geared towards improving the country's infrastructure. These included the implementation of legal, institutional and policy, framework for the development of the Mass Rapid Transit System (The Republic of Kenya, 2018).

The government has incorporated the Expansion of Roads Programme which aims to enhance connectivity both at the regional and domestic levels, reduce urban congestion and boost rural productivity. The realization of this goal is dependent on the construction/rehabilitation of 2,500 Km of conventional roads and 7,500Km Low Volume Sealed Roads. The programme also covers the construction of 40 km of Non-Motorized Transport Facilities, 308 Km of bypasses and 53.3 km of missing links (The Republic of Kenya, 2018). The Road Expansion Programme facilitated the construction and rehabilitation of 2,779Km of roads under the National government and 471 km under County Governments. Both the East Africa Road Network Project (EARNP) and Kenya Transport Sector Support Project were involved in the construction and rehabilitation of 137 km and 132.3km respectively. There was also an upgrade of 450.75 Km to bitumen standards under Low Volume Seal Roads (LVSR) as of 30th September 2017. A total of 208,088.91 Km of the county and national trunk roads were routinely maintained while 5,298.55 Km of National roads were periodically maintained and 765.65Km were maintained under the Roads 2000 Programme (Republic of Kenya, 2018).

Therefore, there has been a dire need for road financing from the national to county level via the relevant road agencies like the Kenya Roads Board (KRB) which manages the Road Maintenance Levy Fund (RMLF). RMLFprovides for the administration of a Road Maintenance Levy Fund, imposition of a road maintenance levy on petroleum fuels and for connected purposes, Kenya Urban Roads Authority (KURA) – maintains, manages and develops roads within urban areas, Kenya Rural Roads Authority (KeRRA) – which maintains, manages and develops National Trunk Roads in Class Cand the Kenya National Highways Authority (KeNHA) – which is maintains, manages and develops National Trunk Roads in Classes S, A and B. By working in unison, these institutions have managed to show positive road improvements in the past decade along with the Vision 2030 goals (The Republic of Kenya, 2018).

Therefore, while road development has significantly improved in the country, there are high costs associated with infrastructure that does not support the prevailing traffic growth, especially in urban areas. Due to poor road construction and maintenance, the results of road traffic crashes cost most countries in the world quite a significant amount of their GDP (WHO, 2021). These costs are associated with road traffic deaths, wasted fuel and increased travel time. Given the maintenance gap despite the high investment by the government, there are yet efforts needed to ensure the roads in poor condition (41% in poor condition) are brought to maintainable standards.

1.1.2 Road User costs in Kenya

Road user costs are incurred in operation and movements when both people and merchandise/goods are being transported along the road. Road user costs on a road also include the costs of accidents and travel delay costs that occur along a particular road stretch. The developments in the road infrastructure in Nairobi County particularly along the Outer Ring Road have reduced travel times to approximately 10 to 15 minutes as of 2020, compared to 45 minutes travel time recorded in 2012, to travel along the same road (Impulso Kenya, 2020). According to the Nairobi Metropolitan Area Transport Authority (NaMATA, 2020), the Kenyan economy loses about $1 billion yearly, through losses in productivity from traffic jams. Most traffic jams in Kenya are experienced along the Nairobi city roads in the peak hours, where Outer Ring Road is one of the major city roads.

1.1.3 Road Safety in Kenya

After malaria and HIV/AIDS, injuries resulting from traffic accidents contribute to the highest number of deaths costing the lives of about 1.3 million people aged between 5-29 years across the world (WHO, 2021). Most countries spend three to five per cent of their gross domestic product on road traffic crashes. Vulnerable road users such as pedestrians account for the largest percentage of road traffic deaths. Low- and middle-income countries contribute to 93% of the world's deaths resulting from road accidents despite owning only 60% of vehicles in the world (WHO, 2021). In and out of Kenyan cities, commuter matatus (which are typically 14-seater minibuses) form the major means of transport. Although they account for only 11% of registered vehicles in Kenya, Raynor and Mirzoev (2014) found that they were involved in 43.6 per cent of road traffic accidents (RTAs) resulting in inpatient admission and 70.2% of (RTAs) passenger casualties were matatu passengers (Soehodho, 2017). An increase in the number of two and three-wheeled vehicles has spiked the number of injuries and deaths on roads (Diaz Olvera et al., 2019; Wang et al., 2019).

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The records of the National Transport and Safety Authority (NTSA) state that at least 3,900 people succumbed to road traffic crashes on Kenyan roads in 2021, compared to 3,200 deaths in 2020 – recording a 16% increase (NTSA, 2021). From trend analysis, the fatality rate per 100 million vehicle miles travelled has increased from 1.26 in 2008 to the highest of 1.37 in 2020(NTSA, 2020). Despite the improvements of Outer Ring Road, it remains the most dangerous in road safety metrics, in that it leads the other roads in the number of road accidents. According to NTSA 2021 road safety report, between January and October 31st of 2021, Outer Ring Road had the highest number of road accidents recorded at 37 accidents, followed by Thika Road with 34, while Waiyaki Way and Mombasa roads that have been under construction of the expressway recorded 31 and 28 accidents respectively.

1.1.4 Road improvement in Outering road, Nairobi Kenya

The Outer Ring Road Project, designed as a congestion-relief highway; existed as a 2-way single carriageway with a lane capacity of 800v/h/l before the upgrade. It had a capacity of 1040 vehicles/hour/lane (v/h/l) which was 30 per cent more than the design capacity for a road of its standard. The Project aimed to improve traffic flow and capacity by expanding the road to a dual carriageway standard, expanding the existing grade intersections, creating two underpasses and constructing Non-Motorized Transport Facilities. The Project also created an allowance of a 9m central median to serve as the corridor for the Bus Rapid Transport (BRT) System in future. Outer Ring Road traverses Nairobi North and Nairobi East districts and serves an estimated population of 2.2 million people (KURA, 2020). In this regard, Outering road has been a keen focus of the government to make improvements and reduce the cases of road fatalities, road-associated costs to users, and congestion among others.

1.2 Statement of the problem

Since the development of roads has been shown to have significant benefits for the economy, to that extent, road safety and reduction of road user costs are contributory components of the Sustainable Development Goals (SDGs). To promote road safety, Kenya has sought to develop and implement strategies, policies and programmes that cut across various sectors. Kenya`s policy framework recognizes road infrastructure as an enabler for achieving the Kenya Vision 2030. More specifically, the development of urban infrastructure promotes efficiency in key economic services and generally supports strong economic growth (Purohit, 2016: Li, 2017).

Despite these efforts, the average road user costs have remained high as well as increased road safety concerns. The Kenyan economy loses about $1 billion annually, through losses in productivity that are attributed to traffic jams, (NaMATA, 2020). Deaths resulting from road accidents are about 3,000 per year which costs the country about 5% of its GDP and this owes to the unprioritized and unenforced road safety programmes (NaMATA, 2020).

According to the statistics released by the Department of Civil Registration, road traffic accidents cost the lives of about 3000 persons yearly. This can be attributed largely to challenges in implementing road safety strategies (Kenya Roads Board, 2021; NTSA, 2020). Moreover, according to Impulso Kenya (2020) and NTSA 2021 road safety report, the Outer Ring Road had the highest road accident rates, which also impacts road user costs in the city negatively. This scenario raises questions about the extent to which road investment results in a reduction in user costs as well as road safety problems. The use of Outer Ring Road, a key road in a large city provides a textbook example of how urban road improvement can impact the economy.

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Literature on this subject has received limited attention, especially for Kenyan urban roads. For instance, Mikolaj et al. (2019) provided insights on the effects of pavement degradation on road users based on the highway development and management tools; however, the focus was only on user costs and not on the safety of the user. Calvo-Poyo (2020) studied the effect of road investment on traffic safety in the interurban road network taking the case of European countries. The study, however, provides little generalizability of its findings to the case of Urban Road improvements in Nairobi County. Khanani et al. (2021) have investigated how road infrastructure development projects have impacted local communities by focusing on the towns of Kisumu and Accra in Ghana.

However, the findings do not provide generalizability/representation to the case of urban roads in Nairobi County. Choi (2020) investigated the road User Costs for Highway Construction Projects Involving a Lane Closure but focused on a case of Korean infrastructure. The above-mentioned studies, though have provided significant insights about road improvements, they have or there are few/scarce comparative studies on urban road improvements, especially in Nairobi County let alone the Outer Ring Road, and that justifies the choice for the effect of road improvement on road user costs and safety of road users in Outer Ring Road.

1.3 Research objective

The study aimed to establish the effects of road improvements on the performance of road users on Outer Ring Road.

1.4 Specific objectives

i. To evaluate the effect of road improvement on road user costs in Outer Ring Road, Nairobi, Kenya.
ii. To assess the effect of road improvement on the safety of road users in Outer Ring Road, Nairobi, Kenya

1.5 Research questions

i. What is the effect of road improvement on road user costs in Outer Ring Road, Nairobi, Kenya?

ii. What is the effect of road improvement on the safety of road users in Outer Ring Road, Nairobi, Kenya?

2.0 LITERATURE REVIEW

2.1 Theoretical Literature

2.1.1 The Transaction Cost Theory

This theory was spearheaded by Niehans (1989) who postulated that infrastructural development towards economic efficiency is achieved by minimizing the costs of exchange. This means that for each transaction there are recurring costs of managing, monitoring and controlling transactions (Young, 2013). The central question is whether a firm can find alternative governance structures to organize transactions (Williamson, 2000). Thus, by the market influence of companies as represented by the transaction cost theory, the firm/company can consider lowering the resources that it deems to be expensive not just to break-even but also to generate profit in a competitive environment (Williamson, 2008). This theory thus is very informative to the governments in estimating transport-sensitive costs for road users and road improvement. They thus, have to appreciate the importance of combining the cost of establishing, implementing and maintaining roads before finally putting the plan into practice.

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This has to be benchmarked against the benefits to be accrued to realize the most out of a given plan to minimize road user costs.

2.1.2 The big push theory of development

The theory was proposed by Rosenstein-Rodan (1943) with later contributions being made by Murphy et al. (1989) to note the contribution of industrialization towards economic growth. Todaro (1989) explains that developing countries need to grow their economies to a level where they can sustain themselves through a massive investment programme designed to promote the building up of economic infrastructure and rapid industrialization. This big push approach is needed because a piecemeal approach will not add up in its effects to the total of the single bits. A minimum quantum of investment is also a necessary but not sufficient condition for success (Meier & Rauch, 1995). This theory applies to road infrastructure investment where certain major roads, highways and bypasses are built to connect rural and urban areas or ease the congestion within a city (that is how government planning influences economic growth). Investment in road infrastructure is thus supported by the theory to help in improving economic growth. This thus enables them to appreciate the importance of creating good road networks to reduce road accidents and road user costs towards improved economic development.

2.2 Empirical Literature

2.2.1 Effects of Road Improvement on the Safety of Road Users

Choocharukul and Sriroongvikrai (2017) investigated how aware international tourists are of the road signs in Thailand. Included in the study were a total of 1091 tourists who were issued with survey questionnaires. In the findings, it was discovered that tourists had less awareness and comprehension of some of the road signs used in Thailand. The most common traffic signs known internationally were the only recognizable signs, while the rest was still ambiguous to many. The findings are relevant to this study since they address the role of designing safe highways in such a way as to help all road users in understanding all road user types.

Albalate and Fageda (2019) aimed to review road safety, and congestion and assess how effective public policies were in urban areas in Spain. They identified road accidents and congestion as essential challenges that affected sustainability in urban areas. The study sought to determine whether road congestion had indirect effects on road casualties and accidents. Between 2008 -2017, data collected from 25 urban areas in Spain revealed that reducing road congestion had a positive impact on the safety of road users. To promote sustainability in terms of the prevention of accidents and reduction of time used in travelling, the study encouraged the use of certain public transport means and also the regulation of parking areas.

Mohan et al. (2020) investigated effective road safety interventions in reducing morbidity and mortality occasioned by road accidents in Kenya. The framework of the study was established through a review of various strategies and policies and also consultations. There was a comprehensive search of previously published and unpublished literature on either completed or ongoing studies to identify primary studies and systematic reviews. In their review, Mohan et al. found that road safety improved when roads had been expanded to accommodate more vehicles. In their recommendations, they urged governments to ensure that more funding was allocated towards road expansion to boost road safety for all road users. The study by Mohan relied on correlation analysis which was critical in generating a relationship between expanding roads and their safety-related effects.

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2.2.2 Effects of Road Improvement on Road User Costs

Kadhim et al. (2020) aimed to assess how a road development project can help reduce various associated costs. Their study involved analyzing a case study and using regression analysis to identify the nature of the relationship between the variables under investigation. Al-Nebai-Baghdad highway, which is a proposed road development project, was chosen for the study because it fitted the criteria of roads undergoing rehabilitation, construction or upgrading. Quantitative data was collected to quantify the identified ESE indicators. Their findings show that upgrading the traffic level of service by adding a lane will reduce user costs because of reduced congestion. From the study, it was found that significant impacts of tolling presented to the economic profitability of both the users and the government. Before the government invests in tolling, there should be a better plan assessment of the investment to ensure that it positively impacts the users of the project.

Do et al. (2020) articulate that there exist social welfare implications posed by the expansion of road capacity. This also entails high occupancy tolls, toll lanes and high occupancy vehicles. To measure the impacts of advancement in roads on welfare, the researcher takes into consideration several variables. These are; transport users, residents, private sector welfare and the regional economy. The research, conducted in Dallas and Tarrant Counties, showed that the high occupancy toll performs well as compared to the other two options and also led to social welfare advancement to a net present value of $6.7 billion. The findings of this study address a crucial question on planning the best road expansion option to improve overall social welfare. The broad approach still extends to the current study where road expansion has been seen as a mechanism to aid in reduced road user costs and road safety improvement. It is critical to ensure that these investments lead to a better life for residents and users thus forming the basis of our current study.

Additionally, approximation outcomes do not give straightforward suggestions on what is to be done but give options on each of the criteria. According to the results, investment costs should not be altered. But there should be a high occupancy toll for impacts on the regional economy. For both corridor travel time and energy and environmental cost, they should utilize all-tolled. The projected social welfare analysis assimilates these contradictory measures by putting a unified index in place and offers the superlative road-investment choice for the community. This study is relevant to the topic because provides a clear association between road improvement and road user costs.

3.0 RESEARCH METHODOLOGY

3.1 Study design

A non-experimental design was adopted for the conduct of this study. In non-experimental designs, the researcher or experimenter compares or uses already existing data, which has its independent variable not manipulated. The non-experimental design involved two arms: where means were generated for road user costs and safety of road users in Outer Ring Road, Nairobi, Kenya before road improvement and after road improvement. That is, the data on road improvement before 2012 (control group) and road improvement in 2020 (experimental group). In the first period, none of the groups was exposed to the experiment (control group) while in the second period, only one of the groups was exposed to the experiment, but not the other (experimental group). This, therefore, incorporated the quantitative research design.

3.2 Theoretical Framework

3.2.1 The Transaction Cost Theory

The current modelling was based on the transaction cost theory spearheaded by Hicks and Niehans (1983). They postulated that infrastructural development towards economic efficiency is achieved by minimizing the costs of exchange. The main idea behind the theory is that infrastructural development towards economic efficiency is achieved by minimizing the costs of exchange. To describe these transactions, there are critical dimensions that ought to be considered such as the frequency of recurrence, uncertainty and the degree to which durable, transaction-specific investments are required to realize the least cost supply. Only recurrent transactions (policing and enforcement costs, maintenance costs, etc.) are of interest (Williamson, 1981).

3.2.2 Model Specification

The model in the current study adopted the following concept, where the calculations were done by dividing the total cost of all transactions by the total number of transactions. Further, the cost per Transaction is the average cost of a single transaction. The total costs in the current study are the road user costs + the costs of cost of Incidents (Fatalities and Severe injuries). Therefore, the model was as follows:

$$\text{Cost per Transaction} = \frac{(\text{road user costs + the costs of cost of Incidents})}{\text{total number of transactions}} \ldots. (3.1)$$

The model to be used was the difference in difference (DID) estimator. This is usually implemented as an interaction term between time and experimental group dummy variables in a regression model. The DID method utilizes the understanding of cross-sectional treatment-control comparisons and before-after studies for a more robust identification (Fredriksson & Oliveira, 2019). The approach in the formula is provided appropriately. For instance, the enforced compound architecture is accurate; the standard error is, on mean, 0: E $[_{\varepsilon i}]$ =0. As a result, the DID disregards pre-treatment results and analyzes the estimate by contrasting the control and treatment subjects' variance differences. The DID estimator is characterized as the variation in mean result prior to and after intervention in a given experimental study. To estimate the effect of road improvement on road user costs and on the safety of road users, DID was estimated as follows;

$$\delta_{DD} = \bar{Y}_1^T - \bar{Y}_0^T - (\bar{Y}_1^C - \bar{Y}_0^C) = \delta \ldots\ldots (3.2)$$

Taking the expectation of this estimator we will see that it is unbiased

$$\delta_{DD} = E[\bar{Y}_1^T] - [\bar{Y}_0^T] - (E[\bar{Y}_1^C] - E[\bar{Y}_0^C])$$

$$= \alpha + \beta + \gamma + \delta - (\alpha + \beta) - (\alpha + \gamma - \gamma)$$

$$= (\gamma + \delta) - \gamma = \delta$$

Where:

0 = individuals in the control group
1 = individuals in the treatment group
t = 0 indicates the pre-treatment period
t = 1 indicates the post-treatment period
$\bar{Y}_0^T$ and $\bar{Y}_1^T$ = the sample averages of the outcome for the treatment group before and after treatment, respectively.
$\bar{Y}_1^C$ and $\bar{Y}_0^C$ = the corresponding sample averages of the outcome for the control group

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This estimation is calculated by deducting the reference cohort's parameter from the intervention cohort's parameter. Therefore, road performance data was taken for two different states and in two time periods (road improvements before implementation in 2012 and road improvements in 2020), and with a sample of data from the population of interest (road user safety and cost of road users), the difference in difference (DID) was estimated by use of multiple linear estimations as follows:

$\bar{Y}1 = \beta 0 + \beta 1 * \delta\ DD + \beta 2 * d2 + \beta 3 * d2.\delta\ DD + \beta 4 * X + \mu$ ……………. (3.3)

Where:

Y_1 = Road safety, given by fatalities and severe injuries.
$\beta 0$ = constant which represents Road safety when the independent variables under consideration are zero
β = the coefficients of the model
δ DD = differences between the experimental and control groups prior to the implementation [Time]

d2 = a dummy variable for the second-time period (implementation in 2020) [Intervention]

d2.δ DD =dummy variable equal to one for those observations in the experimental group in the second period [Time*Intervention]

X= Road improvement

μ =error term

$\bar{Y}2 = \beta 0 + \beta 1 * \delta\ DD + \beta 2 * d2 + \beta 3 * d2.\ \delta\ DD + \beta 4 * X + \mu$……………. (3.4)

Where:

Y_2 = Road user costs, given by travel time delay, cost of fatalities & severe injuries, travel cost and cost of Fuel/km.

$\beta 0$ = constant which represents the Road user costs when the independent variables under consideration are zero

β = the coefficients of the model

δ DD = possible differences between the experimental and control groups prior to the implementation [Time]

d2 = a dummy variable for the second-time period (implementation in 2020) [Intervention]

d2. δ DD = dummy variable equal to one for those observations in the experimental group in the second period [Time*Intervention]

X= Road improvement

μ =error term

3.3 Study Site

The Nairobi Outer Ring Road project was designed to ease congestion on other major highways surrounding it. It is located in Nairobi City County and serves an estimated population of 2.2 million which constitutes 70% of Nairobi City County's population. The road also serves Kangundo Road, Northern Bypass Road, Thika Super Highway, Eastern Bypass Road and Mombasa Road. Overall, the choice of study site provides a meaningful representation of the road sector in Kenya in view of the road serving more than two million people in Kenya's largest city, having received a major facelift in recent years and experiencing incidences of accidents post-improvement.

3.4 Study population

The study used data related to Outer Ring Road which provided information about the motorized road users as well as the non-motorized road users (classified into three categories; pedestrians, bicycles and handcarts) along Outer Ring Road. The data was collected based on the four segments to ensure an efficient survey that is, the Thika Road to Kariobangi section, Kariobangi to Mutindwa section, Mutindwa to Jogoo Rd section and the Jogoo Rd to Tassia Junction.

3.5 Research Instruments

The data in the current study were collected by the use of a secondary data template. The data was collected using the available data from the existing information on safety & traffic aspects for the safety of road users and the cost of road user components respectively.

3.6 Data Types and Sources

The study collected quantitative data which was collected using a secondary data template. The quantitative data was based on road safety and road user costs before (in 2012) and after (in 2020) road improvement along Outering Road. The data in 2012 were collected from Kenyan relevant road agencies and tabulated under the dummy of 0, while the data in 2020 was also collected and tabulated under the dummy of 1. The data was based on a 30-day survey carried out along the Outering Road. The data is shown in Table 1.

Table 1: Description and Measurement of Variables

Variable	Definition of Variable	Measurement
Road improvement	The process of constructing and widening new hard-surfaced lanes, curbing and guttering, and landscaping including footbridges, street lights and walkways subject to the requirements of the authority in charge	• A dummy of 0 and 1. 0 representing road improvement before 2012 and 1 representing road improvement at 2020
Road safety	The measures taken by road users and constructors in ensuring that the roads are in a condition that does not expose the road users to any risks	• The number of fatalities for both 2012 and 2020 • The number of severe/ serious injuries for both 2012 and 2020 • The number of road accidents in both 2012 and 2020
Road User Costs	Road User Costs are the daily incremental costs of travelling resulting from the construction works being performed	• Travel time delay (hours) for both 2012 and 2020 • Cost of fatalities (in KES Billion) for both 2012 and 2020 • Costs of severe/serious injuries (in KES Billion) for both 2012 and 2020
Costs of severe/serious injuries	Costs of severe/serious injuries are the total number of severe/serious injuries * GDP per Capita	• The cost of severe/serious injuries is measured in Kenyan Billion Shillings for both 2012 and 2020 justifiable by the international standards
Cost of fatalities	Cost of fatalities is the total number of fatalities*GDP per Capita	• Cost is in Kenyan Billion Shillings for both 2012 and 2020
Travel time delay	Travel time delay (in hours) is the free flow time + systematic delay + unexplained delay	• Time delay in hours for both 2012 and 2020

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The number of fatalities	The number of fatalities is the total number of road traffic crashes leading to road user deaths	• The number of persons killed due to road accidents in both 2012 and 2020
The number of severe/ serious injuries	The number of severe/ serious injuries is the total number of road traffic crashes leading to severe road user injuries and disability.	• The number of persons injured due to road accidents in both 2012 and 2020
The number of road accidents	Road accidents are the total number of persons injured and deaths due to road accidents	• The number of persons injured and killed due to road accidents in both 2012 and 2020

3.7 Data Collection Procedure

Subject to receiving authoritative consent from the Kenyatta University Graduate School, the study was conducted by use of the secondary data for outer ring road on the following aspects: the type of accident, time of occurrence, injuries, causes, fatalities, state of the road and the identified black spots. Likewise, the data on road user costs were collected on aspects related to traffic flows, which is traffic delay time, hours it takes to travel from Thika Road to Tassia Junction during and off-peak and costs of road traffic accidents fatalities and severe injuries along the road.

3.8 Data analysis

Data processing was done using SPSS software Version 25.0. The data was entered into Excel; sorted, coded, and cleaned before analysis in SPSS 26.0. Descriptive statistics, diagnostic tests and inferential statistics were used to analyze the data. Descriptive statistics involved the generation of minimums, maximums, means, and std. deviations and variances for road user costs and safety of road users in Outer Ring Road, Nairobi, Kenya before and after road improvement. Thereafter, the study also sought to do an estimation of the difference-in-differences in attempts to test the multivariate effect of road improvements on road user costs and the safety of road users along Outer Ring Road, Nairobi, Kenya. The test took a multivariate approach to determine the impact of road improvement on the mean outcomes of road user costs and the safety of road users, depending on 2012 and 2020. and the findings were presented in tables. Statistical significance was based on t-values, p-values mean difference set at $p \leq 0.05$. For statistical significance, the p-values have to be less than 0.05, absolute t-values greater than 1.96 and F values greater than F critical values. The difference in difference (DID) was estimated by use of multiple linear estimations.

4.0 DATA ANALYSIS, PRESENTATION AND INTERPRETATION

4.1 Introduction

This chapter discusses the results of the study in line with the study objectives. The chapter presents various methods of analysis and their output in relation to the study objectives.

4.2 Descriptive Statistics

The study sought to present the comparison in means, median, frequencies, standard deviations and maximums and minimums of the outcomes of road user costs along Outer Ring Road, Nairobi, Kenya in 2012 and in 2020.

4.2.1 Descriptive Statistics for Road User Costs in Outer Ring Road, Nairobi, Kenya

Descriptive Statistics for road user costs along Outer Ring Road were conducted for both 2012 and 2020 to show the respective outcomes of total travel time (Hrs.), costs of severe/serious accidents (Billion KES) and the cost of fatalities (Billion KES) (Table 2).

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Table 2: Descriptive Statistics for Road User Costs

Year (Groups)	2012			2020		
Descriptive Statistics	**Total travel time (Hrs.)**	**Costs of severe/serious accidents (Billion KES)**	**Cost of fatalities (Billion KES)**	**Total travel time (Hrs.)**	**Costs of severe/serious accidents (Billion KES)**	**Cost of fatalities (Billion KES)**
N	24	24	24	24	24	24
Minimum	0.58	9.09	6.82	0.02	3.41	-1.14
Maximum	10.58	11.37	61.39	0.08	5.68	48.89
Median	3.77	9.22	25.15	0.04	4.41	18.00
Std. Deviation	3.33	0.94	14.17	0.02	1.08	14.82
Variance	11.09	889.75	200649.47	0.00	1159.01	219570.63

Table 2 indicates that the median total travel time before road improvement on Outer Ring Road (2012) was 3.77 hours; a figure that was reduced to 0.041 hours after road improvement in 2020. The minimum travel time in 2012 was 0.584 hours and the maximum travel time in 2020 was 10.578 hours while the minimum travel time in 2020 was 0.017 hours and the maximum travel time in 2020 was 0.076 hours. The median cost of severe/serious accidents before road improvement on Outer Ring Road (2012) was KES 9.22 billion which was later reduced to KES 4.41 billion after road improvement in 2020. The minimum costs of severe/serious accidents in 2012 was KES 9.09 billion and the maximum cost of severe/serious accidents in 2012 was KES 1.14 billion while the minimum cost of severe/serious accidents in 2020 was KES 3.41 and the maximum cost of severe/serious accidents in 2020 was KES 5.68 billion.

Likewise, owing to the effects of road improvement on Outer Ring Road, the median costs of fatalities reduced from KES 2.52 billion in 2012 to KES 1.80 billion in 2020. The minimum cost of fatalities in 2012 was KES 6.82 billion and the maximum cost of fatalities in 2020 was KES 6.14 billion while the minimum cost of fatalities in 2020 was KES -1.14 billion and the maximum cost of fatalities in 2020 was KES 4.89 billion. The findings are in line with Wang et al. (2019) who indicated that the release way of the impact energy and the protection worn by the victims are key variables contributing to the severity of road traffic accidents. Kadhim et al. (2020) show that upgrading the traffic level of service by adding a lane will reduce user cost because of reduced congestion. It is worth noting that the study is relevant to the topic of research because it recommends improving the roadside characteristic by considering the width distance (Do et al., 2020).

4.2.2 Descriptive Statistics for the safety of road users along Outer Ring Road, Nairobi, Kenya

Likewise, this section presents the outcomes of the safety of road users (number of fatalities, the number of severe/ serious injuries and the number of road accidents) along Outer Ring Road, Nairobi, Kenya both in 2012 and in 2020 (Table 3).

Table 3: Descriptive Statistics for the safety of road users

Year (Group)	2012			2020		
Descriptive Statistics	**Numb er of**	**The number of severe/ serious**	**The number of road**	**Number of**	**The number of severe/ serious**	**The number of road**

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	fatalities for 30 days	injuries in 30 days	accidents in 30 days	Fatalities for 30 days	injuries in 30 days	accidents in 30 days
N	24	24	24	24	24	24
Minimum	1	8	6	0	3	-1
Maximum	5	10	54	2	5	43
Median	3	9	22	2	4	16
Std. Deviation	0.96	0.83	12.46	0.78	0.95	13.03
Variance	0.91	0.69	155.25	0.60	0.90	169.88

Table 3 indicates that the median number of fatalities before road improvement on Outer Ring Road (2012) was 3 fatalities; a figure that reduced to 1 fatality after road improvement in 2020. The minimum number of fatalities in 2012 was 1 fatality and the maximum number of fatalities in 2020 was 5 fatalities while the minimum number of fatalities in 2020 was 10 fatalities and the maximum number of fatalities in 2020 was 2 fatalities. The median number of severe/ serious injuries before road improvement on Outer Ring Road (2012) was 9 injuries which were later reduced to 4 injuries after road improvement in 2020. The minimum number of severe/ serious injuries in 2012 was 8 injuries and the maximum number of severe/ serious injuries in 2012 was 10 injuries while the minimum number of severe/ serious injuries in 2020 was 3 injuries and the maximum number of severe/ serious injuries in 2020 were 5 injuries.

Likewise, owing to the effects of road improvement on Outer Ring Road, the median number of road accidents reduced from 22.12 in 2012 to 15.83 accidents in 2020. The minimum number of road accidents in 2012 was 6 accidents and the maximum number of road accidents in 2020 was 54 accidents while the minimum number of road accidents in 2020 was -1 accidents and the maximum number of road accidents in 2020 was 43 accidents. The findings are consistent with Albalate and Fageda (2019) who affirmed that reducing road congestion had a positive impact on the safety of road users. According to the research, promoting particular forms of public transit and regulating parking spots may help cities become more self-sustaining, including both perspectives of duration taken travelling and the likelihood of being involved in an incident. Mohan et al. (2020) also found that road safety improved when roads had been expanded to accommodate more vehicles. In their recommendations, they urged governments to ensure that more funding was allocated towards road expansion to boost road safety for all road users. Likewise, Zumrawi (2014) asserted that poor drainage conditions on road pavements had adverse impacts as they caused pavement distress and deterioration in terms of riding quality and safety of all road users. Schepers et al. (2015) revealed that the building of bicycle paths and lanes on roads resulted in a decrease in a reduction of all-cause mortality. Bicycle paths and lanes, in addition to having vehicular lanes, helped reduce accidents that involve cyclists on roads. The overall benefits are significantly large and are crucial in achieving a larger benefit-cost ratio for bicycle infrastructure.

4.3 Model Diagnostic Testing

4.3.1 Test for Equality of Means of the road user costs

The study sought to test of means of road improvement and road user costs on the Outer ring road in 2012 and compare it with the one in 2020 (Table 4). This was done to assess the equality

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of means and variances of the outcomes in 2012 compared to the ones in 2020 (Fisher, 1951). The null hypothesis is that the variances are equal across all samples. Thus, if the p-value is larger than the alpha level (0.05), then the null hypothesis is not rejected indicating that there is equal variance between the test groups. (Derrick et al., 2018; Gastwirth et al., 2009).

Table 4: T-test for means of road user costs

Independent Samples Test	Variable	Total travel time (Hrs.)		Costs of severe/serious accidents (Billion KES)		Cost of fatalities (Billion KES)	
	Group	2012	2020	2012	2020	2012	2020
t-test for Equality of Means	T	5.479	5.479	19.618	19.618	1.709	1.709
	Df	46	23.001	46	45.219	46	45.907
	p-value	0.000	0.000	0.000	0.000	0.094	0.094
	Mean Diff.	3.725	3.725	5731.720	5731.720	7152.807	7152.807

p-value = significance value at 0.05; M.D = mean difference; t = t-values

Table 4 indicates that there is a significant mean difference of 3.725 in the total travel time (p=0.000) along Outer Ring Road in 2012 (before road improvement) compared to 2020 (after road improvement). There was also a significant mean difference of 5731.720 in the costs of severe/serious accidents (p=0.000) along Outer Ring Road in 2012 (before road improvement) compared to 2020 (after road improvement). However, there was no significant mean difference of 7152.807 in the cost of fatalities (p=0.094) along Outer Ring Road in 2012 (before road improvement) compared to 2020 (after road improvement).

The findings agree with Ameratunga et al. (2006) that enhanced road infrastructure increases road safety, which reduces accidents and injuries. It is known that injuries increase road user costs due to increased medical and treatment costs. Improving road transport infrastructure offers real opportunities to reduce road traffic injuries. Szeto (2015) and Pojani and Stead (2015) also noted that technological improvements in road infrastructural developments are vital in addressing environmental issues. The adoption and implementation of technological innovations such as unmanned bridge inspections, concrete sensor systems and security and surveillance help to improve monitoring, security assurance, and maintenance of the roads which are part and parcel of the mechanisms to minimize road user costs and improve road safety. According to Villarreal et al. (2016), improving road transport infrastructure significantly helps reduce transportation costs.

4.3.2 Test for Equality of Means of the safety of road users

This section also presents the test for equality of means of the safety of road users both in 2012 and 2020. The null hypothesis indicates/presupposes that the error variance across the cohorts under study is not varying but is equal (Table 5).

Table 5: T-test for Equality of Means on the safety of road users

Independent Samples Test	Variable	Number of Fatalities		The number of severe/ serious injuries		The number of road accidents	
	Group	2012	2020	2012	2020	2012	2020
	t	8.132	8.132	19.618	19.618	1.709	1.709

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t-test for Equality of Means	df	46	44.148	46	45.219	46	45.907
	p-value	0.000	0.000	0.000	0.000	0.094	0.094
	Mean Diff.	2.042	2.042	5.042	5.042	6.292	6.292

p-value = significance value at 0.05; M.D = mean difference; t = t-values

Table 5 indicates that there is a significant mean difference of 2.042 in the total travel time (p=0.000) and a mean difference of 5.042 in the costs of severe/serious accidents (p=0.000) along Outer Ring Road in 2012 (before road improvement) compared to 2020 (after road improvement). However, there is no significant mean difference of 6.292 in the cost of fatalities (p=0.094) along Outer Ring Road in 2012 (before road improvement) compared to 2020 (after road improvement).

Nevertheless, the findings are consistent with Gichaga (2016) that the expansion of roads like the Nairobi-Thika Highway required a significant investment in signage to cater for the communication and safety of road users. The use of road signs, according to the study, resulted in a decreased rate of accidents happening on the highway. Ezeibe et al. (2017) revealed that the failure of the Nigerian government to erect and maintain traffic signs was a significant issue that affected all road users. Over and over again, the distance between signs and the hazards they warn against is very short. Jackett and Frith (2013) indicated that in areas where there was proper lighting, the roads were classified as safe while the opposite was exact inroads that had poor street lighting. The possibility of an accident occurring at night was high and as a result, authorities had to ensure that visibility on roads was improved through more lighting.

4.3.3 ANOVA Test for the road user costs

ANOVA testing was used to do a comparison between the outcomes of road user cost based on road improvements from 2012 compared to the 2020 road improvements. It tested the variances among a unit of observation and their means by assessing the amount of variation of the travel time, total delays and the total time travel within the North and South Bound streams in 2012 and 2020. The assumption is that the population is selected from a regularly dispersed sample with equal deviation (Table 6).

Table 6: ANOVA results for road improvement and the road user costs

ANOVA		**Sum of Squares**	**df**	**Mean Square**	**F**	**p-value**
Total travel time (Hrs.)	Between Groups	166.491	1	166.491	30.016	0.000
	Within Groups	255.151	46	5.55		
	Total	421.642	47			
Costs of severe/serious accidents (Billion KES)	Between Groups	394.23	1	394.23	384.849	0.000
	Within Groups	47.12	46	1.024		
	Total	441.35	47			
Cost of fatalities (Billion KES)	Between Groups	613.95	1	613.95	2.922	0.094
	Within Groups	966.50	46	210.11		
	Total	102.79	47			

DF= degree of freedom, F = calculated F statistic, Sig = significance level

Between Groups = the variance of each period of study (2012 and 2020)

Within Groups = the variance of observations within each period of study (obs in 2012 and in 2020)

Table 6 indicated a statistically significant effect of road improvement on road user costs given the total travel time (p=0.000) and the costs of severe/serious accidents (p=0.000) in 2012 compared to 2020. However, there was no statistically significant impact of road improvement on road user costs given the cost of fatalities (p=0.094) in 2012 compared to 2020. According to Wang et al. (2019), the release method of impact strength and the safety provided by the casualties are important elements leading to the seriousness of roadway incidents. According to Kadhim et al. (2020), upgrading the traffic level of service by adding a lane will reduce user costs because of reduced congestion. It is worth noting that the study is relevant to the topic of research because it recommends improving the roadside characteristic by considering the width distance (Do et al., 2020). The findings also agree with Ameratunga et al. (2006) that enhanced road infrastructure increases road safety, which reduces accidents and injuries. It is known that injuries increase road user costs due to increased medical and treatment costs. Improving road transport infrastructure offers real opportunities to reduce road traffic injuries. According to Villarreal et al. (2016), improving road transport infrastructure significantly helps reduce transportation costs.

4.3.4 ANOVA Test for the safety of road users

ANOVA testing was done to test the variances among a unit of observation and their means by assessing the amount of variation in the number of fatalities and the cost of fatality in 2012 and 2020. The assumption is that the sample is drawn from the normally distributed population and that the population variance is equal (Table 7).

Table 7: ANOVA results for road improvement and the safety of road users

ANOVA		Sum of Squares	df	Mean Square	F	p-value
Number of Fatalities for 30 days	Between Groups	50.021	1	50.021	66.135	0.000
	Within Groups	34.792	46	0.756		
	Total	84.813	47			
The number of severe/ serious injuries in 30 days	Between Groups	305.021	1	305.021	384.85	0.000
	Within Groups	36.458	46	0.793		
	Total	341.479	47			
The number of road accidents in 30 days	Between Groups	475.021	1	475.021	2.922	0.094
	Within Groups	7477.958	46	162.564		
	Total	7952.979	47			

DF= degree of freedom, F = calculated F statistic, Sig = significance level

Between Groups = the variance of each period of study (2012 and 2020)
Within Groups = the variance of observations within each period of study (obs in 2012 and in 2020)

Table 7 indicated a statistically significant effect of road improvement on the safety of road users given the number of fatalities (p=0.000) and the number of severe/ serious injuries (p=0.000) in 2012 compared to 2020. However, there was no statistically significant impact of

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road improvement on the safety of road users given the number of road accidents (p=0.094) in 2012 compared to 2020.

However, other studies indicate that road improvements play a significant role in the safety of road users. For instance, Zumrawi (2014) asserted that poor drainage conditions on road pavements had adverse impacts as they caused pavement distress and deterioration in terms of riding quality and safety of all road users. Schepers et al. (2015) revealed that the building of bicycle paths and lanes on roads resulted in a decrease in a reduction of all-cause mortality. Bicycle paths and lanes, in addition to having vehicular lanes, helped reduce accidents that involve cyclists on roads. The overall benefits are significantly large and are crucial in achieving a larger benefit-cost ratio for bicycle infrastructure.

4.4 The Difference in Difference Test using the Multiple Linear Estimation for the Safety of Road Users

The study also sought to do an estimation of the difference-in-differences in attempts to test the multivariate effect of road improvements on the safety of road users along Outer Ring Road, Nairobi, Kenya for both 2012 and 2020. This involves the Difference in Difference Tests on the effect of road improvements on the number of fatalities the number of severe/ serious injuries and the number of road accidents.

Table 8: Tests of Between-Subjects Effects of the Mean Outcomes of Safety of Road Users

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Squared
aCorrected Model	Number of Fatalities for 30 days	50.021	1	50.02	66.14	0.000	0.590
	The number of severe/ serious injuries in 30 days	305.021	1	305.02	384.85	0.000	0.893
	The number of road accidents in 30 days	475.021	1	475.02	2.92	0.094	0.060
bIntercept	Number of Fatalities for 30 days	180.188	1	180.19	238.24	0.000	0.838
	The number of severe/ serious injuries in 30 days	1963.521	1	1963.52	2477.40	0.000	0.982
	The number of road accidents in 30 days	17290.02	1	17290.02	106.36	0.000	0.698
cControl Group (2012 & 2020)	Number of Fatalities for 30 days	50.021	1	50.02	66.14	0.000	0.590
	The number of severe/ serious injuries in 30 days	305.021	1	305.02	384.85	0.000	0.893
	The number of road accidents in 30 days	475.021	1	475.02	2.92	0.094	0.060

Running a multivariate regression analysis of road improvements in 2012 and 2020 on Outer Ring Road bounds, Table 8 indicated that there is a significant interaction between the road improvements along outering road, and the safety of road users in 2012 compared to 2020. This was indicated by the mean number of fatalities of 50.02 (p= 0.000), and the mean number of severe/ serious injuries of 305.02 (p= 0.000). However, the mean number of road accidents of 475.02 showed an insignificant relationship between road improvements along outering roads and the safety of road users in 2012 compared to 2020 (p= 0.094). The findings corroborate those of Albalate and Fageda (2019) who affirmed that reducing road congestion had a positive impact on the safety of road users. The study indicated that the promotion of certain modes of

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public transportation and the regulation of parking spaces may contribute to making cities more sustainable, both in terms of the time spent travelling and the probability of being affected by an accident. Mohan et al. (2020) also found that road safety improved when roads had been expanded to accommodate more vehicles. In their recommendations, they urged governments to ensure that more funding was allocated towards road expansion to boost road safety for all road users. Likewise, Zumrawi (2014) asserted that poor drainage conditions on road pavements had adverse impacts as they caused pavement distress and deterioration in terms of riding quality and safety of all road users.

4.5 The Difference in Difference Test using the Multiple Linear Estimation for Road User Costs

The difference-in-differences was also conducted to determine the effect of road improvements on road user costs along Outer Ring Road, Nairobi, Kenya for both 2012 and 2020. This involves the Difference in Difference Tests on the effect of road improvements on total travel time (hrs.), costs of severe/serious accidents (Billion KES) and the cost of fatalities (Billion KES).

Table 9: Tests of Between-Subjects Effects of the Mean Outcomes of Road User Costs

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	p-value	Partial Eta Squared
aCorrected Model	Total travel time (Hrs.)	166.49	1	166.49	30.02	0.000	0.395
	Costs of severe/serious accidents (Billion KES)	394.2313	1	394.23	384.85	0.000	0.893
	Cost of fatalities (Billion KES)	613.9518	1	613.95	2.92	0.094	0.060
bIntercept	Total travel time (Hrs.)	173.968	1	173.97	31.36	0.000	0.405
	Costs of severe/serious accidents (Billion KES)	2537.798	1	2537.80	2477.4	0.000	0.982
	Cost of fatalities (Billion KES)	22346.89	1	22346.90	106.36	0.000	0.698
cControl Group (2012 & 2020)	Total travel time (Hrs.)	166.49	1	166.49	30.02	0.000	0.395
	Costs of severe/serious accidents (Billion KES)	394.2313	1	394.23	384.85	0.000	0.893
	Cost of fatalities (Billion KES)	613.9518	1	613.95	2.92	0.094	0.060

With regard to road user costs, Table 9 indicated that the interaction between the road improvements along Outer Ring Road and the road user costs was significant in 2012 compared to 2020. That was specifically indicated by the mean total travel time of 166.49 (p= 0.000), the mean costs of severe/serious accidents of 394.23 (p= 0.000) except for the mean cost of fatalities of 613.95 which was insignificant (p= 0.094). According to Wang et al. (2019), the release method of impact strength and the safety provided by the casualties are important elements leading to the seriousness of roadway incidents. Kadhim et al. (2020) show that upgrading the traffic level of service by adding a lane will reduce user costs because of reduced congestion. It is worth noting that the study is relevant to the topic of research because it recommends improving the roadside characteristic by considering the width distance (Do et al., 2020). The findings also agree with Ameratunga et al. (2006) that enhanced road infrastructure increases road safety, which reduces accidents and injuries. It is known that injuries increase road user costs due to increased medical and treatment costs. Improving road transport infrastructure offers real opportunities to reduce road traffic injuries. According to

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Villarreal et al. (2016), improving road transport infrastructure significantly helps reduce transportation costs.

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the discussion is done in line with the study objectives. The discussion was done to answer the research questions of the study.

5.2 Summary of the Findings

This section provided a summary of the findings, which was done in line with the objectives of the study. The section provides critical information regarding the most significant treatment outcomes, such as the best effect estimate and the confidence of the evidence for each outcome. Thus, this part specifically presents the study findings to provide clarity on each individual purpose and question within the problem description.

With the focus on the effect of road improvement on road user costs and the safety of road users in Outer Ring Road, Nairobi, Kenya, the study findings generally indicate that there are significant improvements in the outcomes of road user costs and the safety of road users after road improvements. That Outer Ring Road, Nairobi, Kenya has undergone improvements which have significantly been shown with reduced road user costs and improvement in the safety of road users.

With a focus on the safety of road users along the road, the number of fatalities, the number of severe/ serious injuries and the number of road accidents in 2012 were higher than when the road improvements were completed in 2020. Likewise, with regard to road user costs, the travel time (Hrs.), the costs of severe/serious accidents (Billion KES) and the cost of fatalities (Billion KES) in 2012 were found to be high due to major cases recorded of road accidents and travel time. However, after road improvements, the records in 2020 showed that the cost of fatalities, the cost severe/serious accidents and travel time significantly reduced. Thus, based on the multivariate linear estimation findings also, confirmed that there is a significant interaction between the road improvements along the Outer ring road, and the safety of road users in 2012 compared to 2020. Likewise, it can be summarized that there is a significant interaction between the road improvements along Outer Ring Road and the road user costs in 2012 compared to 2020.

5.3 Conclusions

Therefore, the study based on the above findings concludes that there is a significant interaction between the road improvements along Outer Ring Road, and the safety of road users (mean cost of a fatality) in 2012 compared to 2020. Likewise, there is a significant interaction between the road improvements along Outer Ring Road, and the road user costs (mean total time travelled) in 2012 compared to 2020.

It was also noted that at the completion of the project on Outer Ring Road, the casualty figures were lower than at the beginning of the project. The figures for road user costs and safety of road users showed a decreasing trend from the year 2012 before road improvements to 2020 after road improvements. Road improvement figures along the Outer Ring Road indicate that the time of travel on Outer Ring Road has significantly been lowered. This can be attributed to the improvements in terms of improved physical infrastructural structures. Like the improvement in visibility challenges, abrupt lane endings, crash barrier treatments, road markings and general maintenance requirements.

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Therefore, the rehabilitation of the Outer Ring Road has led to significant road safety improvements. This led to the answering of the research questions: The effect of road improvement on road user costs along Outer Ring Road, Nairobi, Kenya is positive and significant. Likewise, the effect of road improvement on the safety of road users along Outer Ring Road, Nairobi, Kenya is positive and significant.

5.4 Policy Implications

Based on the findings of the study, the following policy contributions were proposed:

Arising from reduced accidents due to road improvement, road agencies can enhance road maintenance on accident-prone roads. In view of the findings that road improvement improves road safety, relevant road agencies such as KRB, RMLF, KURA, KeRRA and KeNHA could enhance expenditure on road repair and conservation in order to improve road safety and reduce excessive fatality rates. Spending on road repair and conservation will aid in preventing infrastructure deterioration and extending its useful life. It helps to reduce road mortality, offering the extra value of a safer and more sustainable transportation system.

The study also noted road fatalities are significantly minimized by road improvements/developments, the study also encourages the formulation of road-specific policies which may be applied to different types of road users in the counties. This will ensure the awareness of road users on the matters regarding safety of road usages like proper use of traffic lights, switching of lanes, speed limits etc., which could have an effect on the evaluations of road users and road user costs.

Based on the finding that road user costs were high on the initial poor road condition status for Outer Ring Road, the study recommends initiatives to improve road maintenance to include driver training, road ethics and regular vehicle maintenance to enhance road safety through the utilization of road safety parks where road users can undergo training and drills on road safety aspects.

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