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Improving Road Safety on East Mega Dike Access Road: A Black Spot Investigation and Cost-Benefit Analysis of Proposed Countermeasures Using Safety Performance Function - Empirical Bayes Approach

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Abstract:

Road accidents remain one of the leading causes of death globally, estimated to be in ninth position in 2022. In Bacolor, Pampanga, the East Mega Dike Access Road offers convenient travel between cities. However, a recent rise in road accidents in the locale raised safety concerns. Hence, this study aims to identify high-risk segments and propose cost-effective solutions, balancing safety with economic considerations. Using the Safety Performance Function – Empirical Bayes (SPF-EB) method, the study identified the top three black spot segments: Segment 5 (K2+000 – K2+500), Segment 1 (K0+000 – K0+500), and Segment 12 (K6+295 – K6+795) in order of decreasing priority. Findings from the road safety audit of these segments revealed common road safety issues, including a lack of road barriers, poor nighttime lighting, and inadequate signage, and is projected to have a total accident of 290.64 by 2039 if left unresolved. Moreover, the cost-benefit analyses showed that the most economical solution is to implement a combination of roadway lighting, reflective pavement markings, metal guardrails, rumble strips, and road signages for the black spot segments. This plan is projected to reduce expected crashes by 61% over 15 years and will cost P5,991,596.31 but the benefits were estimated to be P27,039,596.04 after 15 years. Thus, the study recommends implementing this project by the Municipality of Bacolor, supporting the Sustainable Development Goals of providing safe and affordable transport for all.

Keywords **—Road Accident, Safety Performance Function – Empirical Bayes, Black Spot Segments, Road Safety Audit, Cost-Benefit Analysis**

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I. INTRODUCTION

Among the major modes of transportation, road transport is widely recognized for its easy accessibility to people, making it the most used mode of transportation [1],[2]. Also, road transport supports economic development significantly because developing cities are often constructed adjacent to roads [3]. However, as several road projects continue to emerge globally, it is also important to consider the safety of road users. By definition, road safety involves the actions and precautions taken to reduce the occurrence of road accidents [4]. Additionally, it is a shared responsibility of everyone benefiting from the road network [5]. Observing the practices on road safety reduces the risk of road accidents and fatalities and minimizes the economic loss it causes [6]. Thus, all individuals' active participation is required to effectively promote road safety in society.

According to research from the International Road Assessment Program, only 1-3% of the total road construction budgets are needed to improve road users' safety efficiently [7]. This underscores that road awareness is as equally important as the development of road safety interventions. Hence, road safety projects must also involve educating road users rather than focusing on improving safety on the road alone [12]. This approach highlights the significance of the shared responsibility of all road users in developing cost-effective road safety project efforts.

Road accidents result in significant economic burdens, including medical treatment expenses, reduced productivity caused by injuries or deaths, and the requirement for family members to take time away from their jobs or education to care for injured individuals [8]. According to the study [9], these road accidents are impacted by three primary categories: human factors, physical factors, and environmental factors. In 2022, road accidents ranked as the ninth most common cause of death worldwide among all age groups [10].

In the study's locale, the East Mega Dike Access Road, has steadfastly served commuters since its inception. The road's route is shown in Figure 1 below.

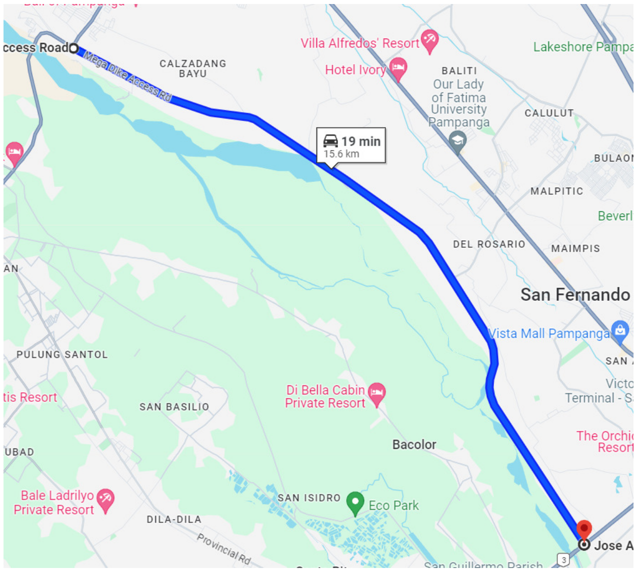

Fig. 1 Terrain Map of East Mega Dike Access Road

Nonetheless, the escalating frequency of vehicular accidents within the area has sparked notable concerns among travellers who rely on this crucial route [11]. An analysis revealed that the road's most perilous section falls within Kilometer 006-007[11]. The preliminary site investigation conducted in 2022 suggests that several factors contribute to the overall road safety concerns, including poor road conditions, limited visibility, and insufficient warning signs. However, the lack of analysis on cost-effective solution could help explain why several suggested countermeasures were not yet realized, as concerned agencies often prioritize projects based on a thorough assessment of their expected benefits [12].

II. METHODS

This study is dedicated to improving the East Mega Dike Access Road safety conditions in Pampanga. The realization of this goal involves a comprehensive multi-method approach organized into three distinct phases: Black Spot Investigation, Accident Prediction and Countermeasure Formulation, and Cost-Benefit Analysis.

A. *Black Spot Investigation*

With the East Mega Dike Access Road chosen as the study locale, the entire span of the road is segmented into ideal homogenous lengths to pinpoint the black spot areas. The timeframe for this analysis was from 2019-2021. The study utilized the Safety Performance Function (SPF) and Empirical Bayes (EB) approach, as outlined in the Highway Safety Manual (HSM) published by the American Association of State Highway and Transportation Officials (AASHTO)[13]. This quantitative approach combines statistical models calibrated to the locale's specific conditions.To conduct this the data gathered for this task is presented in Table 1.

TABLE I
DATA INPUTS FOR BLACK SPOT IDENTIFICATION

Data Needed	Data Collection Method
Road geometry	Geographic Information System (GIS) from Google Earth and Site Investigation
Historical accident data	Requested from PNP Stations
Annual average daily traffic	Manual Counting
Traffic control features	Site Investigation

Safety Performance Function for Base Conditions

The SPF for predicted average frequency for rural two-lane two-way roadway segments is shown in Equation I-1.

$$\boldsymbol{N_{spf\,rs} = AADT \times L \times 365 \times 10^{-6} \times e^{(-0.312)}} \qquad \textbf{\textit{(I-1)}}$$

Where:

$N_{spf\,rs}$ = predicted total crash frequency for roadway segment base conditions;

AADT = average annual daily traffic volume (vehicles per day);

L = length of roadway segment (miles).

For Calculating Annual Average Daily Traffic:

$$\boldsymbol{AADT = \sum_{n}^{i=1} \frac{(V15max\ x\ 4)}{n} \times \frac{1}{K}}$$

Where:

V_{15max} = highest 15-minute traffic count from peak hour

K = K-factor, the proportion of AADT occurring in the peak hour, taken as 15% for rural highways

Calibration for Specific Road Conditions

For rural two-lane two-way undivided roadway segments, the predictive model is shown in Equation I-2:

$$\boldsymbol{N_{predicted\,rs,a} = N_{spf\,rs} \times (AMF_{1r} \times AMF_{2r} \times \ldots \times AMF_{12r})} \textbf{\textit{(I-2)}}$$

Where:

$N_{predictal\,rs,a}$ = predicted average crash frequency with accident modification factors for an individual roadway segment for specific year;

$N_{spf\,rs}$ = predicted average crash frequency for base conditions for an individual roadway segment;

$AMF_{1r} \ldots AMF_{12r}$ = Accident Modification Factors for rural two-way two-lane roadway segments;

Local Calibration Factor

The true value of calibration factor (Cr) is determined as follows:

$$\boldsymbol{C_r = \frac{\sum_{all\ sites} observed\ crashes}{\sum_{all\ sites} predicted\ crashes}} \quad \textbf{\textit{(I-3)}}$$

Final Calibration of Model

For rural two-lane two-way undivided roadway segments with the calibration factor known, the predictive model is shown below:

$$\boldsymbol{N_{predicted\ rsc}} = N_{predictal\ rs,a} \times \boldsymbol{C_r} \qquad \textbf{\textit{(I-4)}}$$

Where:

$N_{predictal\ rsc}$ = predicted average crash frequency that is calibrated for an individual roadway segment for specific year;

$N_{predictal\ rs,a}$ = predicted average crash frequency with accident modification factors for an individual roadway segment for specific year;

C_r = calibration factor for roadway segments of a specific type developed for a geographical area;

Adjustments through Excess Expected Average Crash Frequency

The calibrated crash prediction model incorporates historical crash data to further improve its accuracy through EB adjustments as demonstrated by the following steps.

a. *Calculate Annual Correction Factor*

The annual correction factor is predicted average crash frequency from an SPF for year n divided by the predicted average crash frequency from an SPF for year 1. This factor is intended to capture the effect that annual variations in traffic, weather, and vehicle mix have on crash occurrences.

$$\boldsymbol{C_{n(TOT)} = \frac{N_{predicted,n(TOTAL)}}{N_{predicted,1(TOTAL)}}} \textbf{\textit{(E-1)}}$$

Where:

$C_{n(TOTAL)}$ = Annual correction factor for total crashes

$N_{predicted(TOTAL)}$= Predicted number of total crashes for year n

b. *Calculate Weighted Adjustment*

$$\boldsymbol{w_{TOTAL} = \frac{1}{1+k_{TOT}\times\sum_{n=1}^{N} N_{predicted,n(TOTAL)}}} \qquad \textbf{\textit{(E-2)}}$$

Where:

$N_{expected}$ = expected average crashes frequency for the study period.

$N_{predicted,n}$ = predicted average crash frequency predicted using a SPF for the study period under the given conditions.

w_{TOTAL} = weighted adjustment to be placed on the SPF prediction.

Where:

k = overdispersion parameter from the associated SPF.

$$\boldsymbol{k = \frac{0.236}{L}} \textbf{\textit{(E-2.2)}}$$

Where:

L = length of roadway segment (miles)

c. *Calculate First Year EB-Adjusted Expected Crash Frequency*

$$\boldsymbol{N_{expected,1(TOTAL)} = w_{TOTAL} \times N_{predicted,1(TOTAL)} + (1 - w_{TOTAL}) \times \left(\frac{\sum_{n=1}^{N} N_{observed,y(TOTAL)}}{\sum_{n=1}^{N} C_{n(TOTAL)}}\right)} \textbf{\textit{(E-3)}}$$

Where:

$N_{observed}$ = observed crash frequency at the site over the study period.

d. *Calculate Final Year EB-adjusted Expected Average Crash Frequency*

$$\boldsymbol{N_{expected,n(TOTAL)} = N_{expected,1(TOTAL)} \times C_{n(TOTAL)}} \qquad \textbf{\textit{(E-4)}}$$

e. *Calculate the Excess Expected Average Crash Frequency*

The difference between the predicted estimates and EB-adjusted estimates for each segment is the excess as calculated by the Equation E-5.

$$\boldsymbol{Excess_y = (N_{expected,n(TOTAL)} - N_{predicted,n(TOTAL)})} \quad \textbf{\textit{(E-5)}}$$

Where:

$Excess_y$= Excess expected crashes for year, n

$N_{expected,n}$ = EB-adjusted expected average crash frequency for year, n

$N_{predicted,n}$ = SPF predicted average crash frequency for year, n

f. *Rank Locations*

Rank the segment based on EB-adjusted expected excess crashes calculated

Note:Road segments with a positive value are classified as black spot areas.

The SPF-EB analysis ranked the potential black spot areas based on their crash risk. These identified areas were prioritized and subjected to a comprehensive road safety audit using the Road Safety Audit Checklist by Austroads [14]. This qualitative approach helped identify specific road safety issues and recommend appropriate countermeasures.

B. Accident Prediction and Countermeasure Formulation

Following the comprehensive assessments, the study delved into evaluating potential countermeasures, focusing specifically on the strategic implementation of traffic safety devices. The DPWH Road Safety Design Manual was consulted for guidance on this task[15],[16]. The SPF-EB approach, employed in the initial phase, was utilized to quantitatively assess the potential safety performance improvement on the road through accident prediction.

The road accident prediction was extended over a 15-year horizon to evaluate the project's economic viability for the third phase.The evaluation encompasses two distinct forecasts:

(a) Prediction of future accidents if no countermeasures are implemented, and (b) Prediction of future accidents with countermeasures applied based on black spot priorities.

The predicted future accident using the SPF-EB approach incorporates the Crash Modification Factor (CMF) to account for the anticipated reduction in accident rates following the implementation of countermeasures. The CMF values are derived from comprehensive before-and-after and cross-sectional studies of specific countermeasures. Additionally, the Association of State Highway and Transportation Officials (AASHTO) evaluates these values in terms of the execution of the study involved, and the details are available through their online database called CMF Clearinghouse[17]. This ensures the reliability and accuracy of the accident prediction models when used as a reference.

SPF-EB Method For Predicting Future Accidents: Considering No Action Taken and with Countermeasures Applied

$$\boldsymbol{N_f = N_p\left(\frac{N_{bf}}{N_{bp}}\right)(CMF_{1f})(CMF_{2f})\ldots(CMF_{nf})} \qquad \textbf{\textit{(P-1)}}$$

Where:

N_f = Expected average crash frequency during the future time period for which accidents are being forecast for the segment or intersection in question (i.e., the after period);

N_p = Expected average crash frequency for the past time period for which observed accident history data were available (i.e., the before period);

N_{bf} = Number of accidents forecast by the SPF using the future AADT data, the specified nominal values for geometric parameters, and – in the case of a roadway segment – the actual length of the segment;

N_{bp} = Number of accidents forecast by the SPF using the past AADT data, the specified nominal values for geometric parameters, and – in the case of a roadway segment – the actual length of the segment;

CMF_{nf}= Value of the nth CMF for the geometric conditions planned for the future (i.e., proposed) design.

If the length of the roadway segments are not changed, the ratio N_{bf}/N_{bp} is the same as the ratio of the traffic volumes, $AADT_f/AADT_p$.

C. Accident Prediction and Countermeasure Formulation

The benefits of the suggested countermeasures were quantified using the Human Capital approach. This method evaluates the corresponding benefits from the reduced accidents in terms of medical costs, lost labour output, and property damage.

Accident Cost per Severity

The estimated reduction in average crash frequency can be converted to a monetary value for each year of the service life using Equations C-2 through C-5.

$$\boldsymbol{AM_{(F)} = \Delta N_{expected\,(F)} \times CC_{(F)}} \qquad \textbf{\textit{(C-2)}}$$

$$\boldsymbol{AM_{(S)} = \Delta N_{expected\,(S)} \times CC_{(S)}} \qquad \textbf{\textit{(C-3)}}$$

$$\boldsymbol{AM_{(M)} = \Delta N_{expected\,(M)} \times CC_{(M)}} \qquad \textbf{\textit{(C-4)}}$$

$$\boldsymbol{AM_{(PDO)} = \Delta N_{expected\,(PDO)} \times CC_{(PDO)}} \qquad \textbf{\textit{(C-5)}}$$

Where:

$\boldsymbol{AM_{(F)}}$= Monetary value of the estimated change in average fatal crash frequency for year, y

$\boldsymbol{AM_{(S)}}$= Monetary value of the estimated change in average serious crash frequency for year, y

$\boldsymbol{AM_{(M)}}$= Monetary value of the estimated change in average minor crash frequency for year, y

$\mathbf{AM_{(PDO)}}$= Monetary value of the estimated change in average property damage only (PDO) crash frequency for year, y

$\boldsymbol{CC_{(F)}}$ = Total crash cost for fatal crash severity

$\boldsymbol{CC_{(S)}}$ = Total crash cost for serious crash severity

$\boldsymbol{CC_{(M)}}$ = Total crash cost for minor crash severity

$\boldsymbol{CC_{(PDO)}}$ = Total crash cost for PDO crash severity

Convert Uniform Annual Benefits to a Present Value

When the annual benefits are uniform over the service life of the project, equations C-6 can be used to calculate present value of the project benefits.

$$\boldsymbol{PV_{benefits} = Total\ Annual\ Monetary\ Benefits \times \left(\frac{P}{A}, i, y\right)} \textbf{\textit{(C-6)}}$$

Where:

$PV_{benefits}$ = Present value of the project benefits for a specific site, v

$(\frac{P}{A}, i, y)$ = Conversion factor for a series of uniform annual amounts to present value

$$\boldsymbol{\left(\frac{P}{A}, i, y\right) = \frac{(1.0+i)^{(y)}-1.0}{i\times(1.0+i)^{(y)}}} \textbf{\textit{(C-7)}}$$

i = Minimum attractive rate of return or discount rate (i.e., if the discount rate is 4%, the i = 0.04)

y = Year in the service life of the countermeasure(s)

Additionally, the distribution of accident severity in the predictions was referred from the default distribution of the crash prediction model. Lastly, the project costs were calculated based on the Detailed Unit Price Analysis (DUPA) of the DPWH Program of Works.

The Table 2 and Table 3 present the crash type and severity distribution in the change in expected crash frequency based from the prediction model as outlined in the Highway Safety Manual [13].

TABLE II
CRASH TYPE DISTRIBUTION – BASED ON THE PREDICTION MODEL

Crash Type	Percentage of Total Roadway Segment Crashes
Single Vehicle Crash	63.8
Two Vehicle Crash	36.2
TOTAL	100.0

TABLE III
CRASH SEVERITY DISTRIBUTION – BASED ON THE PREDICTION MODEL

Crash Severity Level	Percentage of Total Roadway Segment Crashes
Fatal Injury	1.3
Serious Injury	16.3
Minor Injury	14.5
Property Damage Only	67.9
TOTAL	100.0

The cost-benefit analysis involved two methods: the Benefit-Cost Ratio (BCR) and the Net Present Value (NPV). The BCR compared the project's total expected benefits to its total expected costs, while the NPV discounted the future benefits and costs to their present values. A sensitivity analysis was also conducted to address uncertainties, particularly those related to the social discount rate. Hence, the data gathered for this task is presented in Table 4.

TABLE IV
DATA INPUTS FOR COST-BENEFIT ANALYSIS OF THE PROPOSED COUNTERMEASURES

Data Needed	Data Collection Method
Project Implementation Costs	Reference from DPWH Program of Works
Medical Expenses per Crash Severity	Requested from nearby selected hospitals in the locale
Average Wage in Pampanga	Requested from Philippine Statistics Authority (PSA)
Property Damage per Crash Severity	Requested from selected insurance companies within Pampanga

Net Present Value (NPV)

$$NPV = PV_{benefits} - PV_{costs} \quad (C\text{-}8)$$

Where:

$PV_{benefits}$= Present value of project benefits

PV_{costs} = Present value of project costs

If the NPV >0, then the individual project is economically justified.

Benefit-Cost Ratio (BCR)

$$BCR = \frac{PV_{benefits}}{PV_{costs}} \quad (C\text{-}9)$$

Where:

BCR = Benefit cost ratio

$PV_{benefits}$ = Present value of project benefits

PV_{costs} = Present value of project costs

If the BCR is greater than 1.0, then the project is economically justified.

Based on the cost-benefit analysis findings, the study concluded with a recommendation for a cost-effective road design improvement for the East Mega Dike Access Road. This recommendation prioritized safety enhancements that provide the greatest return on investment.

III. RESULTS AND DISCUSSION

A. Black Spot Investigation

Using Google Earth's Geographic Information System (GIS), data about the total length of the East Mega Dike Access Road, including horizontal curves and elevation, was determined. Consequently, the road is segmented into thirty-one (31) sections highlighted with distinct colors, as shown in Figure 2. Figure 2 below illustrates the individual road segments of East Mega Dike Access Road.

Fig. 2 Road Segments of East Mega Dike Access Road

Furthermore, the remaining roadway geometric characteristics and traffic control features that were not determined in the GIS were determined by conducting a preliminary road survey. Based on the combined data gathered from the GIS and road survey, the accident modification factors are calculated following the Highway Safety Manual (HSM) guidelines. Table 5 presents the accident modification factors for the roadway geometric characteristics of each road segment along the East Mega Dike Access Road. Additionally, Table 6 presents the accident modification factors for the traffic control features of each segment.

TABLEV
ACCIDENT MODIFICATION FACTORS FOR ROADWAY GEOMETRIC CHARACTERISTICS OF INDIVIDUAL ROAD SEGMENTS

Segment	AMF 1	AMF 2	AMF 3	AMF 4	AMF 5
1	1.05	1.29	1.00	1.00	1.10
2	1.15	1.29	1.00	1.00	1.10
3	1.05	1.29	1.00	1.00	1.10
4	1.12	1.29	1.00	1.00	1.10
5	1.10	1.29	1.00	1.00	1.16

6	1.10	1.29	1.00	1.00	1.10
7	1.15	1.29	1.00	1.00	1.10
8	1.15	1.29	1.02	1.01	1.00
9	1.10	1.29	1.00	1.00	1.16
10	1.05	1.29	1.00	1.00	1.16
11	1.05	1.29	1.00	1.00	1.16
12	1.15	1.29	1.00	1.00	1.16
13	1.10	1.29	1.00	1.00	1.10
14	1.09	1.29	1.05	1.04	1.10
15	1.11	1.29	1.00	1.00	1.00
16	1.19	1.29	1.00	1.00	1.10
17	1.19	1.29	1.00	1.00	1.10
18	1.09	1.29	1.00	1.00	1.16
19	1.05	1.29	1.00	1.00	1.10
20	1.11	1.29	1.00	1.00	1.00
21	1.15	1.29	1.00	1.00	1.10
22	1.04	1.29	1.00	1.00	1.10
23	1.09	1.29	1.09	1.06	1.10
24	1.16	1.29	1.00	1.00	1.10
25	1.09	1.29	1.00	1.00	1.10
26	1.11	1.29	1.00	1.00	1.10
27	1.06	1.29	1.00	1.00	1.16
28	1.10	1.29	1.00	1.00	1.10
29	1.05	1.29	1.00	1.00	1.10
30	1.05	1.29	1.00	1.00	1.10
31	1.03	1.29	1.00	1.00	1.16

TABLE VI
ACCIDENT MODIFICATION FACTORS FOR TRAFFIC CONTROL FEATURES OF INDIVIDUAL ROAD SEGMENTS

Segment	AMF 6	AMF 7	AMF 8	AMF 9	AMF 10	AMF 11	AMF 12
1	1.00	1.00	1.00	1.00	1.31	1.00	1.00
2	1.00	1.00	1.00	1.00	1.31	1.00	1.00
3	1.00	1.00	1.00	1.00	1.31	1.00	1.00
4	1.00	1.00	1.00	1.00	1.31	1.00	1.00
5	1.00	1.00	1.00	1.00	1.22	1.00	1.00
6	1.00	1.00	1.00	1.00	1.22	1.00	1.00
7	1.00	1.00	1.00	1.00	1.22	1.00	1.00
8	1.00	1.00	1.00	1.00	1.14	1.00	1.00
9	1.00	1.00	1.00	1.00	1.22	1.00	1.00
10	1.00	1.00	1.00	1.00	1.31	1.00	1.00
11	1.00	1.00	1.00	1.00	1.31	1.00	1.00
12	1.00	1.00	1.00	1.00	1.31	1.00	1.00
13	1.00	1.00	1.00	1.00	1.31	1.00	1.00
14	1.00	1.00	1.00	1.00	1.31	1.00	1.00
15	1.00	1.00	1.00	1.00	1.31	1.00	1.00
16	1.00	1.00	1.00	1.00	1.31	1.00	1.00
17	1.00	1.00	1.00	1.00	1.31	1.00	1.00
18	1.00	1.00	1.00	1.00	1.31	1.00	1.00
19	1.00	1.00	1.00	1.00	1.31	1.00	1.00
20	1.00	1.00	1.00	1.00	1.31	1.00	1.00
21	1.00	1.00	1.00	1.00	1.31	1.00	1.00
22	1.00	1.00	1.00	1.00	1.31	1.00	1.00
23	1.00	1.00	1.00	1.00	1.31	1.00	1.00
24	1.00	1.00	1.00	1.00	1.31	1.00	1.00
25	1.00	1.00	1.00	1.00	1.31	1.00	1.00
26	1.00	1.00	1.00	1.00	1.31	1.00	1.00
27	1.00	1.00	1.00	1.00	1.31	1.00	1.00
28	1.00	1.00	1.00	1.00	1.31	1.00	1.00
29	1.00	1.00	1.00	1.00	1.31	1.00	1.00
30	1.00	1.00	1.00	1.00	1.31	1.00	1.00
31	1.00	1.00	1.00	1.00	1.31	1.00	1.00

Table 5 shows that the segments have different AMF 5 values resulting from the individual segments having different average slopes determined by Google Earth's GIS. On the other hand, Table 6 shows that the segments have the same AMF 9 values, resulting from the absence of two-way left turn lanes for the whole length of the East Mega Dike values from the site investigation. These values are incorporated into the Safety Performance Function (SPF) base conditions predictions to include the roadway geometric characteristics in the prediction model.

Figure 3 below presents the AADT values for each road segment from 2019 to 2024.

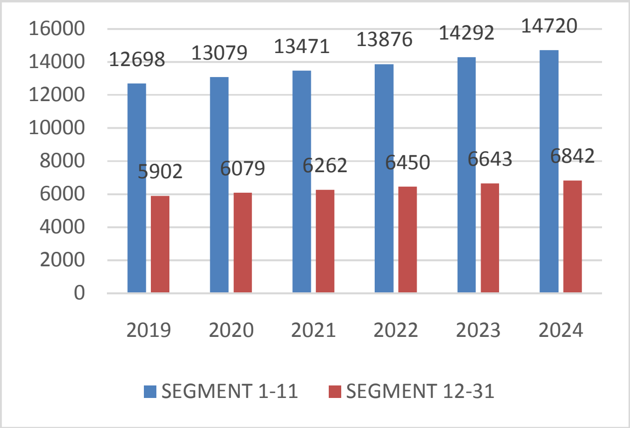

Fig. 3Annual Average Daily Traffic of Road Segments for Year 2019-2024

Table 7 below shows the summary of observed crashes along East Mega Dike Access Road from the years 2019-2021 per segment. The following values are obtained from the road accidents reports gathered from the Police Stations.

TABLE VII
SUMMARY OF OBSERVED CRASHES ALONG EAST MEGA DIKE ACCESS ROAD

Segment	**Year**		
	2019	**2020**	**2021**
1-SP1	2	5	3
2-SP2	0	0	0
3-SP3	0	0	0
4-SP4	1	3	0
5-SP5	0	3	14
6-SP6	1	0	1
7-SP7	2	2	3
8-LC1	0	0	1
9-SP8	1	0	1
10-SP9	0	1	0
11-SP10	0	3	4
12-SP11	3	6	1
13-SP12	0	1	1
14-LC2	0	1	1
15-SP13	0	2	1
16-SP14	0	0	1
17-SP15	0	0	1
18-SP16	1	0	0
19-SP17	0	0	2

20-SP18	0	0	1
21-SP19	0	0	0
22-SP20	0	0	0
23-LC3	0	0	1
24-SP21	0	0	0
25-SP22	0	0	0
26-SP23	0	0	0
27-SP24	0	0	0
28-SP25	0	0	0
29-SP26	0	0	0
30-SP27	0	0	0
31-SP28	0	0	0
TOTAL	**11**	**27**	**37**

Table 8 compares average predicted crashes, average observed crashes, expected crashes, excess expected crashes, and the priority ranking for black spot investigation for each road segment.

TABLE VIII
BLACK SPOT IDENTIFICATION: AVERAGE PREDICTED, OBSERVED CRASH, AND EXPECTED CRASHES FOR YEAR 2019-2021

Segment	**Average Predicted Crash**	**Average Observed Crash**	**Expected Crash**	**Excess Expected Crash**	**Rank**
1-SP1	1.15	3.33	4.04	2.89	2
2-SP2	1.25	0.00	0.48	-0.77	30
3-SP3	1.15	0.00	0.47	-0.68	29
4-SP4	1.23	1.33	1.93	0.71	6
5-SP5	1.18	5.67	6.59	5.41	1
6-SP6	1.12	0.67	1.18	0.05	16
7-SP7	0.89	2.33	2.87	1.98	4
8-LC1	2.88	0.33	1.63	-1.26	31
9-SP8	1.18	0.67	1.19	0.01	17
10-SP9	1.21	0.33	0.84	-0.37	28
11-SP10	1.21	2.33	3.01	1.80	5
12-SP11	0.61	3.33	3.25	2.64	3
13-SP12	0.38	0.67	0.80	0.42	8
14-LC2	0.55	0.67	0.92	0.36	10
15-SP13	0.51	1.00	1.14	0.63	7
16-SP14	0.61	0.33	0.66	0.06	14
17-SP15	0.61	0.33	0.66	0.06	14
18-SP16	0.58	0.33	0.65	0.07	13
19-SP17	0.53	0.67	0.90	0.36	9
20-SP18	0.51	0.33	0.62	0.10	12
21-SP19	0.58	0.00	0.37	-0.21	26
22-SP20	0.40	0.00	0.26	-0.15	19
23-LC3	0.42	0.33	0.54	0.13	11
24-SP21	0.59	0.00	0.37	-0.21	27
25-SP22	0.55	0.00	0.36	-0.19	22
26-SP23	0.56	0.00	0.37	-0.20	24
27-SP24	0.57	0.00	0.37	-0.20	13
28-SP25	0.56	0.00	0.36	-0.19	23
29-SP26	0.53	0.00	0.36	-0.18	8
30-SP27	0.53	0.00	0.36	-0.18	20
31-SP28	0.35	0.00	0.23	-0.12	18
TOTAL	**25.00**	**25.00**	**37.77**		

Based on the table above, data analysis revealed the top three black spot segment priorities to be Segments 5 (K2+000 - K2+500), 1 (K0+000 – K0+500), and 12 (K6+295 - K6+795), in order of decreasing importance with an excess expected crashes of 5.41, 2.89, and 2.64, respectively.

Figure 4 depicts the critical areas along the East Mega Dike Access Road, highlighted in red for emphasis. The segments were color-coded based on the priority level assigned during the black spot identification process. Red represents the most concerning zones, followed by orange and white for the least critical areas.

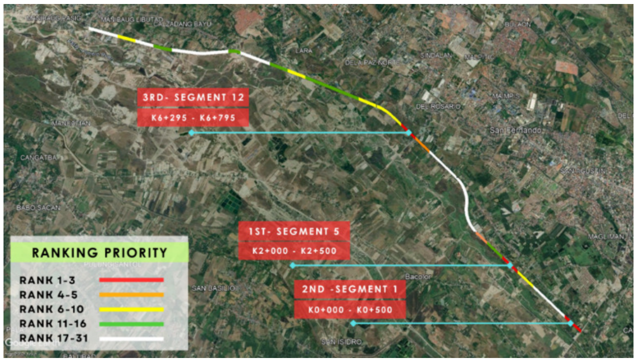

Fig. 4Black Spot Segments along the East Mega Dike Access Road

Road Safety Audit

The following are the results of Road Safety Audit for the top 3 priorities:

Road Alignment and Cross Section

- Segment 5 - Upon conducting the Road Audit, it is noticeable that there are numerous blind spots in the area considering the tree branches extending to the road, plants, and grass obstructionthat make it difficult to see ahead of the road.
- Segment 1 - Warning and advisory speed signs are installed as required, especially since this segment is the entry and exit point of the East Mega Dike Road located at Bacolor. However, when it comes to the traffic volume, the number of lanes on both entry and exit lanes is insufficient as it cannot fully accommodate the average daily traffic, which causes congestion along the intersection of the Mega Dike Road and the Jose Abad Santos Avenue Road.
- Segment 12 – Limited warning and guide signs are installed but are insufficient due to the damaged intersection advisory signage, which is obstructed by trees from a further sight distance.

Signs and Lighting

- Segment 5 – Lighting is absent for the whole segment, resulting in a high risk of accidents during nighttime, as it is nearly impossible to see the road's pavement markings and approaching vehicles without the vehicles' beam lights. Furthermore, no signage is present in the area that indicates warnings, regulatory, directional, restrictions, etc.

- Segment 1 - Lighting is not adequately provided since the entry point is the only area on the segment that has lighting. Moreover, signage is present in this segment. However, these signs are not noticeable enough to warn, guide, and inform the drivers of the approaching road. Additionally, some signages have low visibility due to fading paint colors, damaged signage plates, and the absence of reflectorized signages along the segment, making it almost zero visibility during nighttime. The road does not possess any lighting except at the entry point. Restrictions for vehicles entering the road are also present due to the vertical clearance signage at the entry point.
- Segment 12 – Lighting is insufficient along the Del Rosario and Dolores intersection, with only lights at the merging roads and none along the rest of the segment leading to Mega Dike Road. Signage exists but lacks visibility and effectiveness in warning, guiding, and informing drivers about the upcoming road. Some signs have low visibility due to faded paint, damaged plates, and a lack of reflectors, making them almost invisible at night without proper lighting except at the intersection. Vehicle entry restrictions exist as vertical clearance in the area is present but damaged.

Crash Barriers and Clear Zones

- Segment 5 – This segment was observed to have no clear zones. Additionally, crash barriers are installed throughout the segment, which is necessary to risk falls along the area due to steep side slopes. The length of some of the crash barriers on the segment is not adequate. It does not possess any delineators to promote the visibility of the crash barriers, especially during the night. Damaged crash barriers are also present on the segment, and colors from the paint applied on the crash barriers are fading, making its visibility impossible for both daytime and nighttime.
- Segment 1 – Clear zones are less than 1ft, while the crash barriers are installed constantly along the whole segment of the road; however, some crash barriers are observed to have inconsistent placement since some of the crash barriers along this area are damaged. Additionally, the visibility of these crash barriers is poor due to fading marks and paints and the absence of delineators on the barriers, which makes it hard to see both daytime and nighttime.
- Segment 12 - The clear zones measure less than 1ft, and crash barriers are installed consistently along the entire road segment. However, some of these barriers are inconsistently placed and damaged in certain areas. Furthermore, the visibility of these crash barriers is compromised by fading marks and paint, making them difficult to see both during the day and at night.

B. Accident Prediction and FormulationofCountermeasures:Traffic Safety Devices

Countermeasures for 1st Black Spot Priority – Segment 5 (K2+000 - K2+500)

The Segment 5 features only a straight path ahead, thus, the following are the possible combination of the suggested countermeasures applicable for the road segment:

Countermeasure I: Install lighting and metal guardrails.
Countermeasure II: Install reflectorized pavement markings and metal guardrails.
Countermeasure III: Install lighting, reflectorized pavement markings, and metal guardrails.

Conforming to the design standards, Figure 5, 6, and 7 below presents the two-dimensional view of the proposed Countermeasure I, II, and III respectively.

Fig. 5 2D View of the Proposed Countermeasure I on Segment 5

Fig. 6 2D View of the Proposed Countermeasure II on Segment 5

Fig. 7 2D View of the Proposed Countermeasure III on Segment 5

Table 9 presents the expected crash frequency and its associated changes, along with suggested countermeasures, for the period from 2025 to 2039 for the segment.

TABLE IX
EXPECTED CRASH FREQUENCY WITHOUT AND WITH COUNTERMEASURES FOR YEAR 2025-2039 FOR SEGMENT 5

Year	**Expected Crashes without Countermeasure**	**Expected Crashes with Countermeasure I**	**Expected Crashes with Countermeasure II**	**Expected Crashes with Countermeasure III**
2025	7.42	2.47	3.19	2.17
2026	7.64	2.55	3.28	2.23
2027	7.87	2.62	3.38	2.30
2028	8.11	2.70	3.48	2.37
2029	8.35	2.78	3.59	2.44
2030	8.60	2.87	3.70	2.51
2031	8.86	2.95	3.81	2.59
2032	9.12	3.04	3.92	2.67
2033	9.40	3.13	4.04	2.75
2034	9.68	3.23	4.16	2.83
2035	9.97	3.32	4.28	2.91
2036	10.27	3.42	4.41	3.00
2037	10.58	3.52	4.55	3.09
2038	10.89	3.63	4.68	3.18
2039	11.22	3.74	4.82	3.28
TOTAL	**137.97**	**45.97**	**59.29**	**40.32**

Countermeasures for 2nd Black Spot Priority – Segment 1 (K0+000 - K0+500)

The Segment 1 features a T-junction at its entry point from Bacolor and follows a straight path ahead, thus, the following are the possible combination of the suggested countermeasures applicable for the road segment:

Countermeasure I: Install lighting, warning sign (advisory speed), and transverse rumble strips.
Countermeasure II: Install reflectorized pavement markings, metal guardrails, warning sign (advisory speed), and transverse rumble strips.
Countermeasure III: Install lighting, reflectorized pavement markings, metal guardrails, warning sign (advisory speed), and transverse rumble strips.

Figure 8, 9, and 10 below presents the two-dimensional view ofthe proposed Countermeasure I, II, and III respectively.

Fig. 8 2D View of the Proposed Countermeasure I on Segment 1

Fig. 9 2D View of the Proposed Countermeasure II on Segment 1

Fig. 10 2D View of the Proposed Countermeasure III on Segment 1

Table 10 shows the segment's anticipated number of crashes and reduced number with the proposed countermeasures for 2025 to 2039.

TABLE X
EXPECTED CRASH FREQUENCY WITHOUT AND WITH COUNTERMEASURES FOR YEAR 2025-2039 FOR SEGMENT 1

YEAR	**Expected Crashes without Countermeasure**	**Expected Crashes with Countermeasure I**	**Expected Crashes with Countermeasure II**	**Expected Crashes with Countermeasure III**
2025	4.55	1.77	1.12	0.76
2026	4.68	1.83	1.16	0.79
2027	4.82	1.88	1.19	0.81
2028	4.97	1.94	1.23	0.83
2029	5.12	2.00	1.26	0.86
2030	5.27	2.06	1.30	0.88
2031	5.43	2.12	1.34	0.91

2032	5.59	2.18	1.38	0.94
2033	5.76	2.25	1.42	0.97
2034	5.93	2.32	1.46	1.00
2035	6.11	2.39	1.51	1.03
2036	6.29	2.46	1.55	1.06
2037	6.48	2.53	1.60	1.09
2038	6.68	2.61	1.65	1.12
2039	6.88	2.68	1.70	1.15
TOTAL	**84.55**	**33.01**	**20.86**	**14.19**

Countermeasures for 3rd Black Spot Priority – Segment 12 (K6+295 - K6+795)

The segment 12 features a crossroad just about on its entry point from Bacolor and follows a straight path ahead. Thus, the following are the possible combinations of the suggested countermeasures applicable for the road segment:

> *Countermeasure I:* Install lighting, regulatory sign (stop sign), warning sign (advisory speed), and transverse rumble strips.
>
> *Countermeasure II:* Install reflectorized pavement markings, metal guardrails, regulatory sign (stop sign), warning sign (advisory speed), warning sign (stop sign), and transverse rumble strips.
>
> *Countermeasure III:* Install lighting, reflectorized pavement markings, metal guardrails, regulatory sign (stop sign), warning sign (advisory speed), and transverse rumble strips.

Figure 11, 12, and 13 below presents the two-dimensional view of the proposed Countermeasure I, II, and III.

Fig. 11 2D View of the Proposed Countermeasure I on Segment 12

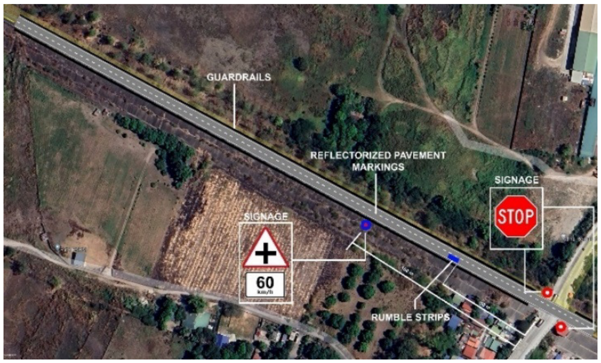

Fig. 12 2D View of the Proposed Countermeasure II on Segment 12

Fig. 13 2D View of the Proposed Countermeasure III on Segment 12

Table 11 indicates the expected number of crashes for the years 2025 through 2020 without implementing any countermeasures and when the proposed countermeasures are realized.

TABLE XI
EXPECTED CRASH FREQUENCY WITHOUT AND WITH COUNTERMEASURES FOR YEAR 2025-2039 FOR SEGMENT 12

YEAR	Expected Crashes without Countermeasure	Expected Crashes with Countermeasure I	Expected Crashes with Countermeasure II	Expected Crashes with Countermeasure III
2025	3.66	1.12	0.70	0.48
2026	3.77	1.15	0.73	0.49
2027	3.89	1.18	0.75	0.51
2028	4.00	1.22	0.77	0.52
2029	4.12	1.26	0.79	0.54
2030	4.25	1.29	0.82	0.56
2031	4.37	1.33	0.84	0.57
2032	4.50	1.37	0.87	0.59
2033	4.64	1.41	0.89	0.61
2034	4.78	1.46	0.92	0.63
2035	4.92	1.50	0.95	0.64
2036	5.07	1.54	0.98	0.66
2037	5.22	1.59	1.00	0.68
2038	5.38	1.64	1.04	0.70
2039	5.54	1.69	1.07	0.72
TOTAL	**68.11**	**20.74**	**13.11**	**8.91**

C. *Cost-Benefit Analysis of Proposed Countermeasures*

Tables 12 and 13 below present the detailed cost per unit of the countermeasures recommended based on the road audit results.

TABLE XII
PROJECT DIRECT COST OF INVOLVED COUNTERMEASURES PER UNIT IN ₱

Countermeasure	**Qty.**	**Unit**	**Direct Cost Per Unit (₱)**			**Total Direct Cost (₱)**
			Material	**Labor**	**Equipment**	
Lighting						
Single Arm Post with Street Light (8m, LED, 130W)	1	each	52,842.20	3,838.80	1,278.00	57,959.00
Pavement Markings						
Reflectorized Thermoplastic Pavement Markings (White)	1	sq.m	558.90	29.78	72.17	660.85
Road Signs						
Regulatory Signs (Stop Sign – R1-1)	1	each	5,971.76	601.17	1,508.69	8,081.62
Warning Signs (Advisory Speed – W8-1)	1	each	7,669.19	601.17	1,508.69	9,779.05
Rumble Strips						
Reflectorized Thermoplastic Rumble Strips	1	sq.m	651.36	23.77	44.95	720.08
Roadside Barriers						
Metal Guardrail (Metal Beam) Including Post	1	ln.m	85.34	168.26	2,789.26	3,042.86
Metal Beam End Piece	1	each	36.24	202.00	1,350.00	1,588.24

TABLE XIII
TOTAL PROJECT COST OF INVOLVED COUNTERMEASURES PER UNIT IN ₱

Countermeasure	**Total Direct Cost (₱)**	**Indirect Cost Per Unit (₱)**				**Total Cost (₱)**
		Mark-up %	**Value (₱)**	**5% VAT**	**Mark-up + VAT**	
Lighting						
Single Arm Post with Street Light (8m, LED, 130W)	57,959.00	0.20	11,591.80	3,477.54	15,069.34	73,028.34
Pavement Markings						
Reflectorized Thermoplastic Pavement Markings (White)	660.85	0.20	132.17	39.65	171.82	832.67
Road Signs						
Regulatory Signs (Advisory Speed)	8,081.62	0.20	1,616.32	484.90	2,101.22	10,182.84
Warning Signs (Stop Sign)	9,779.05	0.20	1,955.81	586.74	2,542.55	12,321.60
Rumble Strips						
Reflectorized Thermoplastic Rumble Strips	720.08	0.20	144.02	43.20	187.22	907.30
Roadside Barriers						
Metal Guardrail (Metal Beam) Including Post	3,042.86	0.18	547.71	179.53	727.24	3,770.10
Metal Beam End Piece	1,588.24	0.18	285.88	93.71	379.59	1,967.83

Road Accident Costing

The project's benefits were calculated in terms of the potential reduction in accidents due to the implemented countermeasures by the human capital approach. These benefits include preventing expenses on medical costs, lost wages, and property damage. Medical cost data were collected from V.L. Makabali Memorial Hospital Inc., a private hospital in San Fernando, Pampanga. Table 14 presents the classified medical costs per accident severity.

TABLE XIV
MEDICAL COST PER ACCIDENT SEVERITY FROM V.L. MAKABALI MEMORIAL HOSPITAL INC.

Accident Severity	Average Medical Cost (₱)	Average Number of Hospital Days
Mild	42,337.87	3.00
Severe	108,318.42	5.00
Fatal	108,318.42	N/A

Table 14 shows that the accident costs for severe and fatal are the same. As the hospital does not have data for the average medical cost for fatal accidents, the cost for severe accidents is the same as fatal accidents, per the crash costing guidelines from the Highway Safety Manual (HSM).

Data on hospitalization days and the average wage of citizens in the locale are used to calculate lost wages due to road accidents. Hence, the Philippine Statistics Authority (PSA) regional office provided average wage information for Region III citizens in 2022, which was ₱20,029. Additionally, PSA data revealed the average age of Filipinos killed in road accidents to be 39 years old [18]. This information helps estimate lost labor output for fatal accidents. Table 15 presents the lost labor output based on accident severity.

TABLE XV
LOST LABOR OUTPUT COST PER ACCIDENT SEVERITY

Accident Severity	Average Lost Labor Output Cost (₱)
Property Damage Only	N/A
Mild	2,731.23
Severe	4,552.05
Fatal	6,249,048.00

Data for property damage costs were collected from selected insurance within the locale, namely the Standard Insurance Inc. Table 16 presents the classified property damage costs per accident severity.

TABLE XVI
PROPERTY DAMAGE COST PER ACCIDENT SEVERITY FROM STANDARD INSURANCE INC.

Accident Severity	Average Property Damage Cost (₱)
Property Damage Only	46,639.33
Mild	145,602.47
Severe	681,373.00
Fatal	932,848.33

The total accident cost per accident severity was calculated by summing the gathered data on medical costs, lost wages, and property damage costs. Table 17 presents the total accident cost per accident severity.

TABLE XVII
AVERAGE ACCIDENT COST PER ACCIDENT SEVERITY

Accident Severity	Average Accident Cost (₱)
Property Damage Only	46,639.33
Mild	190,671.56
Severe	794,243.47
Fatal	7,290,214.76

Net Present Value and Benefit-Cost Ratio for Segment 5 (K2+000 - K2+500)

Tables 18 and 19 below summarize the project benefits and project costs of the suggested countermeasures for Segment 5. Table 18 presents the present worth of the annual benefits, while Table 19 presents the total project costs for the countermeasures.

TABLE XVIII
PRESENT WORTH OF THE ANNUAL MONETARY BENEFITS IN ₱ OF THE SUGGESTED COUNTERMEASURE COMBINATIONS FOR SEGMENT 5

YEAR	Present Worth Factor	Countermeasure I (₱)	Countermeasure II(₱)	Countermeasure III(₱)
2025	0.91	1,736,673.94	1,485,262.52	1,843,415.32
2026	0.83	1,626,158.33	1,390,745.81	1,726,107.07
2027	0.75	1,522,675.52	1,302,243.81	1,616,263.89
2028	0.68	1,425,777.99	1,219,373.75	1,513,410.74
2029	0.62	1,335,046.66	1,141,777.24	1,417,102.78
2030	0.56	1,250,089.15	1,069,118.68	1,326,923.51
2031	0.51	1,170,538.02	1,001,083.86	1,242,482.92
2032	0.47	1,096,049.24	937,378.52	1,163,415.83
2033	0.42	1,026,300.65	877,727.16	1,089,380.28
2034	0.39	960,990.61	821,871.80	1,020,056.08
2035	0.35	899,836.66	769,570.86	955,143.42
2036	0.32	842,574.33	720,598.17	894,361.56
2037	0.29	788,955.96	674,741.93	837,447.65
2038	0.26	738,749.67	631,803.80	784,155.52
2039	0.24	691,738.33	591,598.11	734,254.72
TOTAL		**17,112,155.06**	**14,634,896.02**	**18,163,921.28**

TABLE XVIX
TOTAL PROJECT COST OF EACH SUGGESTED COUNTERMEASURES FOR SEGMENT 5 (K2+000 - K2+500)

Project Cost (₱)	Countermeasure I	Countermeasure II	Countermeasure III
Direct Cost	2,761,666.53	2,115,167.85	3,390,265.92
Indirect Cost	686,815.36	518,725.70	850,251.20
TOTAL	**3,448,481.90**	**2,633,893.55**	**4,240,517.12**

Figure 14 and Figure 15 present the cost-benefit analysis for the suggested countermeasure for Segment 5. Figure 110 illustrates the net present value (the total project benefits on a considered timeframe minus the total project cost) of the three possible combinations of suggested countermeasures for 5, 10, and 15-year horizons. In contrast, Figure 15 illustrates the benefit-cost ratio with the same analysis timeframe.

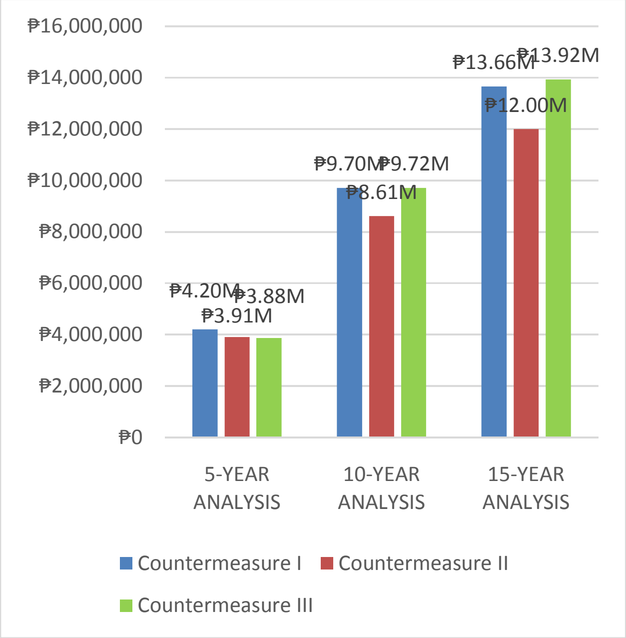

Fig. 14Net Present Value of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 5 (K2+000 - K2+500)

Based on Figure 14, Countermeasures I, II, and III show almost the same net present values after five years, with values of ₱4,197,850.55, ₱3,905,509.57, and ₱3,875,782.68, respectively, with Countermeasure I being the highest for Segment 5. However, after 10 and 15 years, Countermeasure III has the highest net present values of ₱9,718,041.29 and ₱13,923,404.16, respectively. On the other hand, Countermeasure II falls behind by only a few million, with net present values of ₱3,905,509.57, ₱8,612,689.59, and ₱12,001,002.46, respectively.

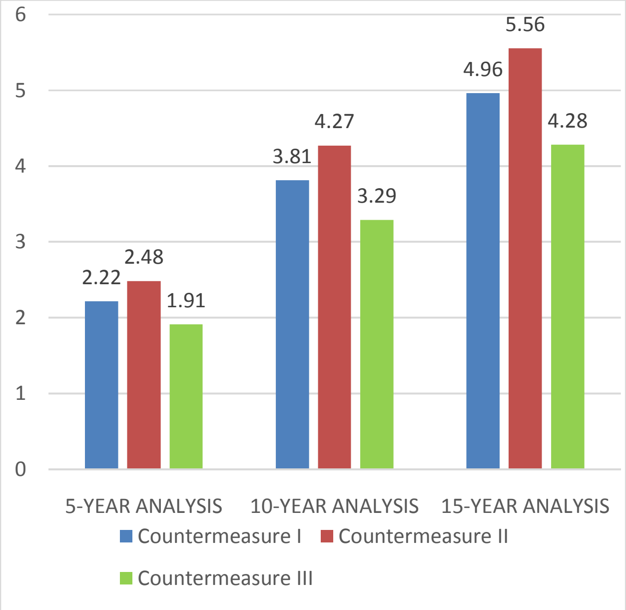

Fig. 15Benefit-Cost Ratio of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 5 (K2+000 - K2+500)

Based on Figure 15, Countermeasure II had the highest benefit-cost ratio for Segment 5 across all analyzed timeframes, with values of 2.48, 4.27, and 5.56 after 5, 10, and 15 years, respectively. Countermeasure III was ahead of a few million in net present values compared to Countermeasure II. However, Countermeasure II was consistent in its economic feasibility for 5, 10, and 15-year analyses based on its benefit-cost ratio. Thus, Countermeasure II is the most economical strategy for Segment 5 based on its net present value and benefit-cost ratio.

Net Present Value and Benefit-Cost Ratio for Segment 1 (K0+000 - K0+500)

Tables 20 and 21 below summarize the project benefits and project costs of the suggested countermeasures for Segment 1. Table 20 presents the present worth of the annual benefits, while Table 21 presents the total project costs for the countermeasures.

TABLE XX
PRESENT WORTH OF THE ANNUAL MONETARY BENEFITS IN ₱ OF THE SUGGESTED COUNTERMEASURE COMBINATIONS FOR SEGMENT 1 (K0+000 - K0+500)

YEAR	**Present Worth Factor**	**Countermeasure I(₱)**	**Countermeasure II(₱)**	**Countermeasure III(₱)**
2025	0.91	972,813.99	1,202,162.93	1,328,181.22
2026	0.83	910,907.65	1,125,661.65	1,243,660.60
2027	0.75	852,940.80	1,054,028.64	1,164,518.56
2028	0.68	798,662.75	986,954.09	1,090,412.83
2029	0.62	747,838.75	924,147.92	1,021,022.93
2030	0.56	700,249.01	865,338.51	956,048.74
2031	0.51	655,687.71	810,271.51	895,209.27
2032	0.47	613,962.13	758,708.78	838,241.41
2033	0.42	574,891.81	710,427.31	784,898.78
2034	0.39	538,307.79	665,218.30	734,950.67
2035	0.35	504,051.84	622,886.23	688,181.08
2036	0.32	471,975.81	583,248.01	644,387.74
2037	0.29	441,940.99	546,132.23	603,381.25
2038	0.26	413,817.47	511,378.36	564,984.26
2039	0.24	387,483.63	478,836.10	529,030.72
TOTAL		**9,585,532.15**	**11,845,400.55**	**13,087,110.06**

TABLE XXI
TOTAL PROJECT COST OF EACH SUGGESTED COUNTERMEASURES FOR SEGMENT 1 (K0+000 - K0+500

Project Cost (₱)	**Countermeasure I**	**Countermeasure II**	**Countermeasure III**
Direct Cost	1,316,258.49	3,638,332.46	4,913,430.52
Indirect Cost	342,227.21	883,626.41	1,215,151.91
TOTAL	**1,658,485.70**	**4,521,958.87**	**6,128,582.43**

Figure 16 and Figure 17 below show the cost-benefit analysis of the proposed countermeasure for Segment 1. Figure 16 depicts the net present value of three combinations of suggested countermeasures over five, ten, and fifteen years.

In contrast, Figure 17 presents the benefit-cost ratio throughout the same analysis timeframe.

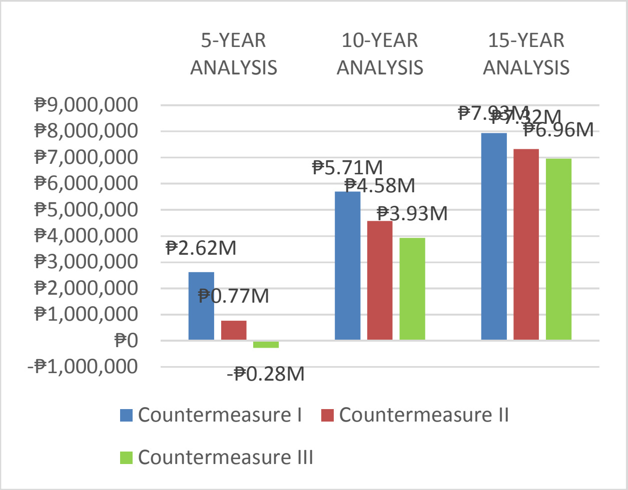

Fig. 16Net Present Value of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 1 (K0+000 - K0+500)

Based on Figure 16, Countermeasure III has a negative net present value after five years, with a value of ₱280,786.30, depicting that the return on investment for the project has not been met yet, while Countermeasure I has the highest positive value of ₱2,624,678.24. Moreover, Countermeasure I has the highest value of ₱7,927,046.45 after 15 years, with Countermeasure II falling only a few hundred thousand behind, with a value of ₱7,323,441.68. On the other hand, implementing Countermeasure III yields a net present value of ₱3,928,562.58, and ₱6,958,527.63 after 10 and 15 years, which is the lowest among the three countermeasures.

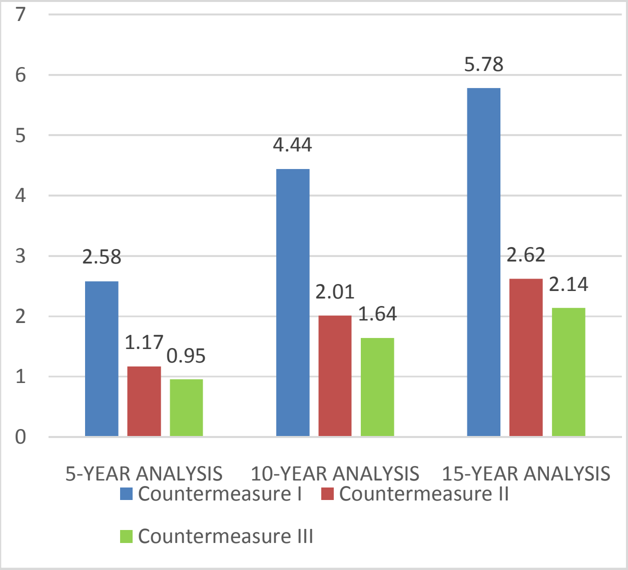

Fig. 17Benefit-Cost Ratio of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 1 (K0+000 - K0+500)

Based on Figure 17 above, Countermeasure I has the highest benefit-cost ratio for Segment 1 across all analyzed timeframes, with values of 2.58, 4.44, and 5.17 after 5, 10, and 15 years, respectively. While Countermeasures I, II, and III have almost the same net present values across the different analysis timeframes, Countermeasures I's benefit-cost ratio shows a significant value gap compared to Countermeasures II and III. Hence, Countermeasure I is the most practical strategy for Segment 1 based on its net present value and benefit-cost ratio.

Net Present Value and Benefit-Cost Ratio for Segment 12 (K6+295 - K6+795)

Tables 22 and 23 below summarize the project benefits and project costs of the suggested countermeasures for Segment 12. Table 22 presents the present worth of the annual benefits, while Table 23 presents the total project costs for the countermeasures.

TABLE XXII
PRESENT WORTH OF THE ANNUAL MONETARY BENEFITS IN ₱ OF THE SUGGESTED COUNTERMEASURE COMBINATIONS FOR SEGMENT 12 (K6+295 - K6+795)

YEAR	**Present Worth Factor**	**Countermeasure I (₱)**	**Countermeasure II (₱)**	**Countermeasure III (₱)**
2025	0.91	894,184.54	1,038,306.91	1,117,496.52
2026	0.83	837,281.89	972,232.83	1,046,383.11
2027	0.75	784,000.32	910,363.47	979,795.09
2028	0.68	734,109.39	852,431.25	917,444.50
2029	0.62	687,393.33	798,185.62	859,061.66
2030	0.56	643,650.12	747,391.99	804,394.10
2031	0.51	602,690.57	699,830.68	753,205.39
2032	0.47	564,337.53	655,296.00	705,274.14
2033	0.42	528,425.14	613,595.35	660,393.05
2034	0.39	494,798.09	574,548.37	618,368.04
2035	0.35	463,310.94	537,986.20	579,017.35
2036	0.32	433,827.51	503,750.72	542,170.79
2037	0.29	406,220.31	471,693.85	507,669.01
2038	0.26	380,369.93	441,676.97	475,362.80
2039	0.24	356,164.57	413,570.26	445,112.44
TOTAL		**8,810,764.18**	**10,230,860.49**	**11,011,148.00**

TABLE XXIII
TOTAL PROJECT COST OF EACH SUGGESTED COUNTERMEASURES FOR SEGMENT 12 (K6+295 - K6+795)

Project Cost (₱)	**Countermeasure I**	**Countermeasure II**	**Countermeasure III**
Direct Cost	1,348,584.97	3,751,294.60	5,026,392.67
Indirect Cost	350,632.09	911,303.22	1,242,828.72
TOTAL	**1,699,217.06**	**4,662,597.82**	**6,269,221.39**

Figure 18 and Figure 19 present the cost-benefit analysis of the proposed countermeasures for Segment 12. Figure 18 illustrates the net present value of three different combinations of suggested countermeasures over five, ten, and fifteen years, whereas Figure 19 shows the benefit-cost ratio over the same timeframe of analysis.

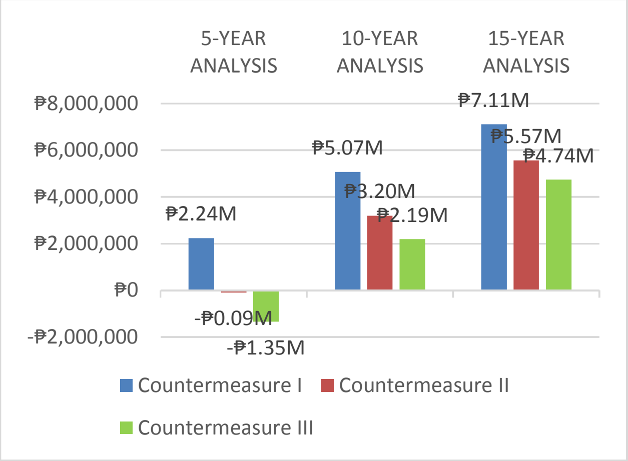

Fig. 18Net Present Value of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 12 (K6+295 - K6+795)

Based on Figure 18, Countermeasure II and II yielded a negative net present value after five years of ₱91,077.75 and ₱1,349,040.51, respectively. Analysis indicates that these countermeasures project costs are still higher than the project benefits offered after five years. However, the net present value after 10 and 15 years shows a positive value for both Countermeasures II and III, indicating that the return on investment for these projects happens a few years more after the first five years. On the other hand, implementing Countermeasure I has the highest net present value across three different timeframes of analysis, with values of ₱2,237,752.41, ₱5,071,653.86, and ₱7,111,547.12 after 5, 10, and 15 years, respectively.

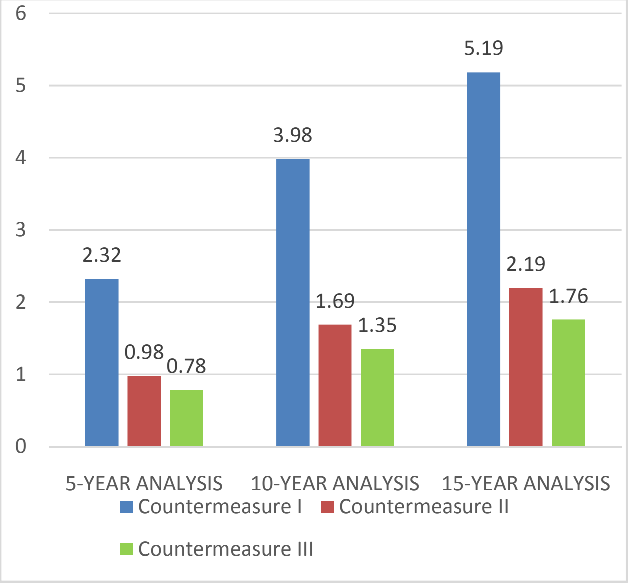

Fig. 19Benefit-Cost Ratio of the Suggested Combination of Countermeasures for 5, 10, and 15-Year Analysis for Segment 12 (K6+295 - K6+795)

Based on Figure 19 above, Countermeasure I offers the most favorable benefit-cost ratio for Segment 12 across all analyzed timeframes, with values of 2.32, 3.98, and 5.19 after 5, 10, and 15 years, respectively. Furthermore, Countermeasures II and III had a benefit-cost ratio lower than 1, indicating that the project could be more economically justified after five years. While Countermeasure III has the lowest projected crashes by 2039, its benefit-cost ratio is the lowest among the three. Additionally, Countermeasure II is the second cost-effective option based on the figure. Hence, Countermeasure I is the most practical choice for Segment 12 based on its net present value and benefit-cost ratio.

Cost-Effective Proposed Countermeasures

Based on the cost-benefit analyses, all three suggested combinations of countermeasures per black spot priorities were cost-effective after 15 years. This highlights the practical application of traffic safety devices, as evaluated by several studies [19]-[21].

However, Countermeasure II, which involves installing metal guardrails and reflectorized pavement markings along the segment, yielded the highest benefit among the three for the first black spot priority (Segment 5). Additionally, Countermeasure I was identified as the most cost-effective solution for Segments 1 and 12, including installing lighting, signage, and rumble strips. Hence, the strategic implementation of these traffic safety devices can help lessen the economic burden posed by road accidents when realized from the identified black spot priorities.

If no action is taken, a significant economic loss will be observed in the future. Figure 20 below presents the anticipated number of road accidents for the top three black spot priorities after 5, 10, and 15 years. Also, Figure 21 below illustrates the forecasted combined present worth of road accident costs after 5, 10, and 15 years for the top three black spot priorities when the suggested countermeasures were not implemented.

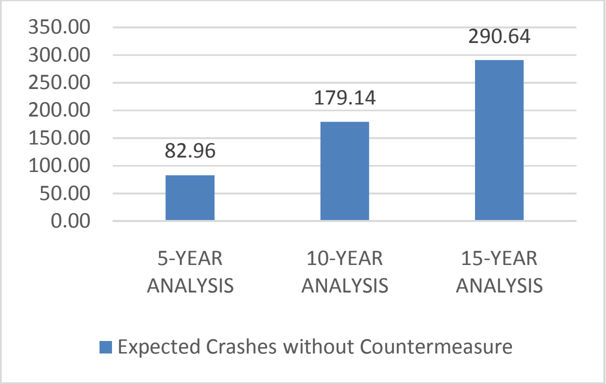

Fig. 20Expected Crash Frequency without Countermeasures for Year 2025-2039 for Top Three Black Spot Priorities

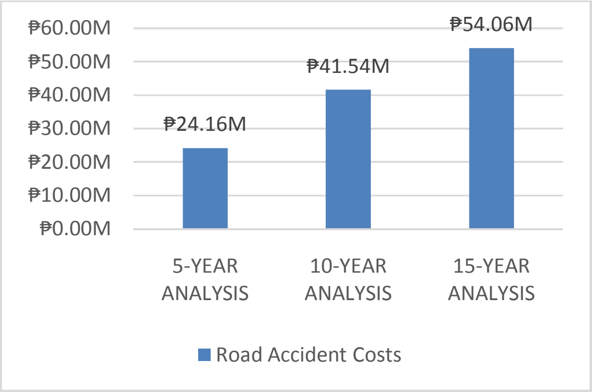

Fig. 21Economic Loss from Road Accidents for Year 2025-2039 for Top Three Black Spot Priorities

Based on Figure 20 and Figure 21, the communities benefiting from the road access provided by the segments will suffer a substantial economic burden from road accidents, with an anticipated number of 82.96 accidents after five years, 179.14 after ten years, and 290.64 after fifteen years. These accidents will cost around ₱24,155,123.38 after five years, ₱41,542,415.79 after ten years, and ₱54,058,101.70 after fifteen years. Thus, it is imperative to implement the identified most-economic countermeasures to prevent these losses.

Figure 22through Figure 24 below visually present these countermeasures in a 2-dimensional View for the top three black spot priorities.

Fig. 222-Dimensional Layout Plan of Proposed Countermeasure for 1st Black Spot Priority (Segment 5: K2+000 - K2+500)

Fig. 232-Dimensional Layout Plan of Proposed Countermeasure for 2nd Black Spot Priority (Segment 1: K0+000 - K0+500)

Fig. 242-Dimensional Layout Plan of Proposed Countermeasure for 3rd Black Spot Priority (Segment 12: K6+295 - K6+795)

Tables 24 and 25 present the project costs for implementing the identified most cost-effective proposed countermeasures for the top three black spot priorities.

TABLE XXIV
PROJECT DIRECT COST OF PROPOSED COUNTERMEASURES FOR TOP THREE BLACK SPOT PRIORITIES

Countermeasure	**Qty.**	**Unit**	**Direct Cost (₱)**			**Total Direct Cost (₱)**
			Material	**Labor**	**Equipment**	
Lighting						
Single Arm Post with Street Light (8m, LED, 130W)	44	each	2,325,056.94	168,907.20	56,232.00	2,550,196.14
Pavement Markings						
Reflectorized Thermoplastic Pavement Markings (White)	951.2	sq.m	531,625.68	28,324.84	68,648.86	628,599.38
Road Signs						
Regulatory Sign (Advisory Speed, Stop	4	each	23,887.04	2,404.68	6,034.76	32,326.48

Sign)						
Warning Signs (Advisory Speed – W8-1)	4	each	30,676.76	2,404.68	6,034.76	39,116.20
Rumble Strips						
Reflectorized Thermoplastic Rumble Strips	60	sq.m	39,081.78	1,426.06	2,696.80	43,204.64
Roadside Barriers						
Metal Guardrail (Metal Beam) Including Post	487.5	ln.m	41,601.16	82,024.31	1,359,766.51	1,483,391.99
Metal Beam End Piece	2	each	72.48	404.00	2,700.00	3,176.48
TOTAL						**4,780,011.31**

TABLE XXV
TOTAL PROJECT COST OF PROPOSED COUNTERMEASURES FOR TOP THREE BLACK SPOT PRIORITIES

Countermeasure	**Total Direct Cost (₱)**	**Indirect Cost (₱)**				**Total Cost (₱)**
		Mark-up %	**Value**	**5% VAT**	**Mark-up + VAT**	
Lighting						
Single Arm Post with Street Light (8m, LED, 130W)	2,550,196.14	0.20	510,039.23	153,011.77	663,051.00	3,213,247.13
Pavement Markings						
Reflectorized Thermoplastic Pavement Markings (White)	628,599.38	0.20	125,719.88	37,715.96	163,435.84	792,035.22
Road Signs						
Regulatory Signs (Stop Sign – R1-1)	32,326.48	0.20	6,465.30	1,939.59	8,404.88	40,731.36
Warning Signs (Advisory Speed – W8-1)	39,116.20	0.20	7,823.24	2,346.97	10,170.21	49,286.41
Rumble Strips						
Reflectorized Thermoplastic Rumble Strips	43,204.64	0.20	8,640.93	2,592.28	11,233.21	54,437.85
Roadside Barriers						
Metal Guardrail (Metal Beam) Including Post	1,483,391.99	0.18	267,010.56	87,520.13	354,530.68	1,837,922.67
Metal Beam End Piece	3,176.48	0.18	571.77	187.41	759.18	3,935.66
TOTAL						**5,991,596.31**

From Tables 24 and 25 above, the total direct project cost will be ₱4,780,011.31. Taking account of the indirect costs, including the markup value and value-added taxes, the total project cost is now ₱5,991,596.31.

From the detailed project cost breakdown above, the project benefits were to be expected once realized. Figure 25below presents the expected crashes after 5, 10, and 15 years, considering no action was taken along with the reduced crashes when the suggested countermeasures were to be implemented. Furthermore, Figure 26 below compares the economic loss, project costs, project benefits, and net present value after 5, 10, and 15 years for the three black spot priorities.

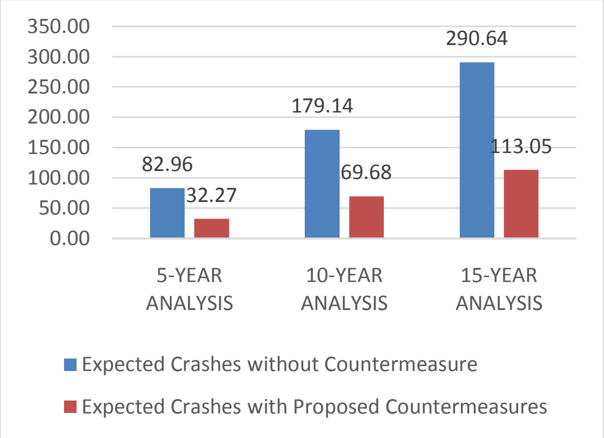

Fig. 25Expected Crash Frequency without Countermeasures and with Proposed Countermeasures for Year 2025-2039 for Top Three Black Spot Priorities

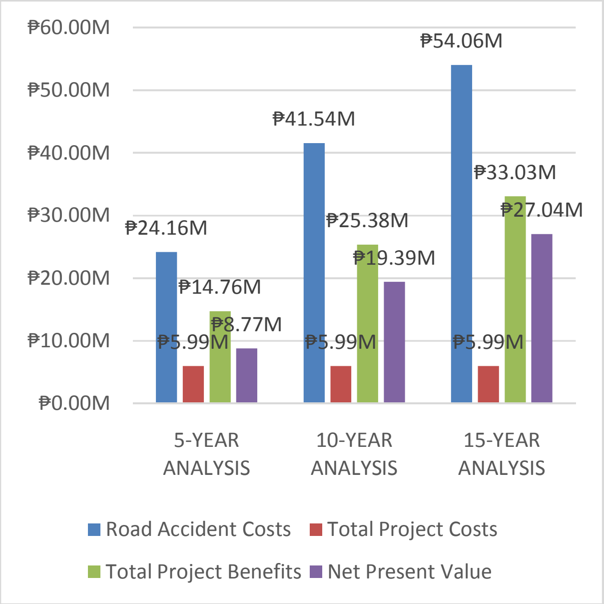

Fig. 26Economic Loss versus Project Costs and Project Benefits for Year 2025-2039 for Top Three Black Spot Priorities

Based on Figure 24 and Figure 25, the total projected number of crashes from the top three black spot priorities by 2039 is 290.64, which costs ₱54,058,101.70. Implementing the proposed countermeasures will reduce it to 113.05, which is a 61% crash reduction, preventing a ₱33,031,192.35 worth of economic loss as opposed to when no countermeasures are realized. Implementing the proposed countermeasures requires an investment of ₱5,991,596.31 but will yield a net present value of ₱27,039,596.04 after 15 years. Hence, implementing the proposed countermeasures will provide a significant return in terms of economic aspects. This proposal aims to assist the Municipality of Bacolor and the DPWH Regional Office in ensuring the safety of all road users on the East Mega Dike Access Road in the most practical way.

IV. CONCLUSIONS

Based on the findings of the study, Segments 5, 1, and 12 were the top three identified black spot areas along the East Mega Dike Access Road. These areas exhibit similar characteristics of road safety issues as enumerated below:

- No clear zones and inadequate roadside barrier protection from steep side slope.
- Inadequate driver visibility at night due to insufficient lighting/road delineation.
- Poor road sign conditions/lacking road signs, and are not placed in advance.

Thus, the following countermeasures are proposed in which are identified to be the most-economical solution:

For 1st Black Spot Priority (Segment 5: K2+000 - K2+500)

- ✓ Install reflectorized pavement markings
- ✓ Install metal guardrails

For 2nd Black Spot Priority (Segment 1: K0+000 - K0+500)

- ✓ Install lighting
- ✓ Install warning sign (advisory speed)
- ✓ Install transverse rumble strips.

For 3rd Black Spot Priority (Segment 12: K6+295 - K6+795)

- ✓ Install lighting
- ✓ Install warning sign (advisory speed)
- ✓ Install regulatory sign (stop sign on minor approaches)
- ✓ Install transverse rumble strips

Considering the identified black spot locations and their corresponding crash prediction modeling, the proposed countermeasures present a targeted approach to addressing road safety concerns on the East Mega Dike Access Road. These interventions aim to significantly reduce expected crashes while maximizing cost-effectiveness. While the primary function of the East Mega Dike may be flood mitigation, the increased traffic volume due to its role as a travel time-saving route necessitates prioritizing the safety of all road users.

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