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Research Article

# Assessment of How Multimodal and Geometric Improvements Reduce Road-Crash Frequency on the 18 Mazoria-Ashewa Meda Corridor

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## Abstract

Road traffic crashes represent a critical public health and safety concern in rapidly urbanizing regions across Ethiopia, mainly affecting vulnerable road users. This study assesses the safety impacts of proposed multimodal and geometric corridor development interventions along the high traffic 18 Mazoria-Ashewa Meda Corridor in Addis Ababa. Using a mixed-methods, historical crash data across 12 equal segments (500m length), field observations, regression modeling and stakeholder perception surveys were analyzed. The assessments revealed severe infrastructure deficiency: 83.3% of segments lacked continuous walkways and 100% lacked dedicated bike lanes and bus bays. Major junctions were strongly correlated with crash severity (r=0.688, p=0.013). multiple regression modeling confirmed major junctions as the dominant predictor of the Weighted Severity Index (B=40.214, p=0.02). Segment 11 (Kidanemihret roundabout) emerged as the primary blackspot (Crash Frequency (CF)=36, representing 31.3% of total crashes) due to steep gradient (~7%) and substandard geometry. Given the absence of post-intervention crash data and data limitation, Crash Modification Factors (CMFS) from the FHWA Clearinghouse and the Highway Safety Manual (HSM) were applied to project safety benefits. The projected interventions demonstrate expected reductions of 32% for dedicated bike lanes (CMF=0.68), 65% for continuous walkways (CMF=0.35), 44% for right-turn geometry modification (CMF=0.558), and 68% for left-turn/ U-turn geometry prohibitions (CMF=0.32). The hazardous Kidanemihret roundabout redesigned into a priority junction to eliminate heavy vehicle rollover risks on steep gradients. Statical evidence, CMF projections and stakeholder perceptions collectively indicate that the interventions will improve road safety.

## Keywords

Road Safety, Crash Modification Factors, Vulnerable Road Users, Weighted Severity Index, Corridor Development, Non-Motorized Transport, Addis Ababa

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# 1. Introduction

## 1.1. Background

Road traffic crashes remain a leading cause of mortality and injury worldwide, particularly in developing nations where rapid urbanization outpaces safe infrastructure provision. In Ethiopia, vulnerable road users (VRUs) specifically pedestrian and cyclists account for a major proportion of fatal road incidents, with pedestrian deaths compromising approximately 37% of national road fatalities [14]. To address these mobility and safety challenges, comprehensive urban development programs are being executed across key transport corridors in Addis Ababa and Sheger City [3, 4].

The 18 Mazoria-Ashewa Meda Corridor along the A4 radial route represents a strategic arterial carrying significant portion of traffic entering and leaving Addis Ababa. However, high congestion, mixed traffic steams, unsafe geometric designs and lacking non-motorized transport (NMT) infrastructure have rendered the corridor highly accident prone.

## 1.2. Objectives

This study aims to:

1) Assess how the multimodal and geometric improvements reduce crash frequency and severity along the corridor.
2) Establish statistical relationships between roadway parameters, junction configuration and crash severity.
3) Integrate stakeholder perspectives to inform safe and sustainable corridor design.

# 2. Methodology

## 2.1. Study Area and Segmentation

The study corridor located in Addis Ababa along Ethiopia's A3 radial road (connecting Addis Ababa to the northwest), the corridor starts 18 Mazoria intersection and ends at Ashewa meda.

The corridor was divided in to 12 segments of 500m using Civil 3D software to create discrete spatial units of analysis.

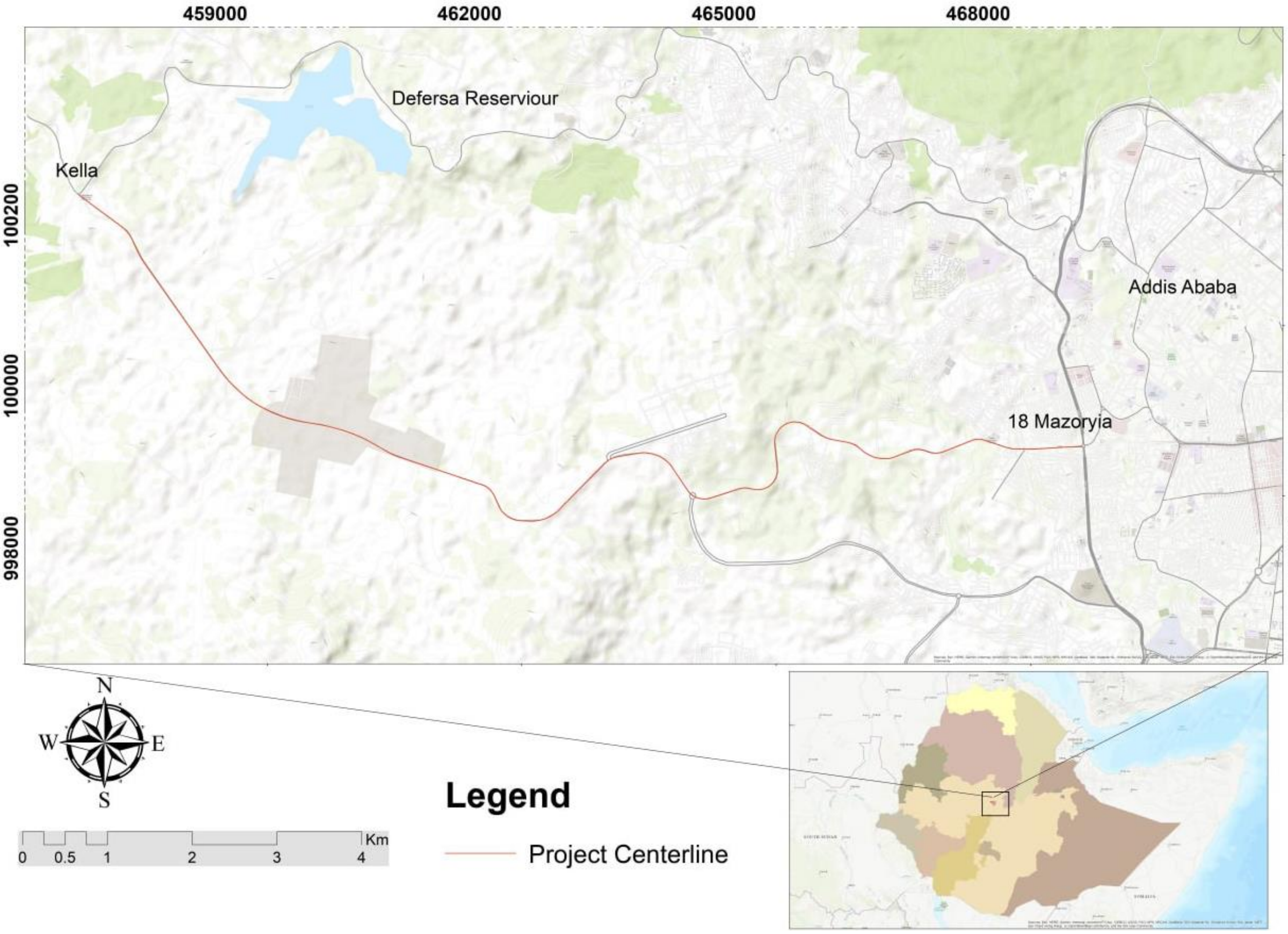


*Figure 1. Study area location map.*


*Figure 2. Road segmentation using Civil C3D.*

## 2.2. Data Sources and Preparation

1) *Secondary Crash Data:* Historical crash records (2014-2020) were obtained from the Federal Police Commission and Addis Ababa Traffic Agency.
2) *Field Assessments:* Observational geometric audit recorded lane width, number of lanes, shoulder width, walkway availability, presence of bike lanes, bus bays and major junction locations.
3) *Stakeholder Survey:* a structure survey captured qualitative feedback from pedestrians, drivers, cyclists, and project consultants.

## 2.3. Analytical Methods

1) *Weighted Severity Index (WSI):* used as the primary dependent variable to quantify crash impact per segment:

WSI = 3 (Fatal injury) + 2 (Serious injury) + 1 (Slight injury)

2) *Statistical Analysis:* Descriptive statistics, Pearson Correlation analysis, multiple linear regression, simple linear regression, non-parametric Mann-Whitney U tests were executed in SPSS.
3) *Crash Modification Factor (CMF) Projection:* Applied to estimate expected safety impacts for constant variables (bike lanes, bus bays) excluded from statistical modeling:

Crash Reduction Percentage = (1-CMF)×100%

# 3. Result and Discussion

## 3.1. Existing Baseline Deficiencies

Field assessments revealed a dominant lack of vulnerable road user infrastructure and safety provisions across the corridor:

1) *Walkways:* Absent on 83.3% of segments (N=10)
2) *Bike Lanes and Bus Bays:* Absent across 100% of segments (N=12).
3) *Cross-Sectional Transitions:* 83.3% of the corridor consists of a 2-lane cross-section, widening abruptly to 4 lanes near Segment 1 (18 Mazoria) which created a bottleneck collision zone.

*Table 1. Summary of geometric and multimodal condition of the corridor.*

| Geometric elements | Value/Range | N | Variation |
|---|---|---|---|
| Lane width | 3.5m (constant) | 12 | 100% (no variation) |
| Number of lanes | 2 to 4 | 12 | 2 lanes: 83.3%, 4 lanes: 16.7% |
| Shoulder width | 0 to 1.5m | 12 | Mean = 1.25m, SD = 0.5839 |
| Walkway present | Yes = 2 segments, No = 10 segments | 12 | 16.7% present, 83.3% absent |
| Bike lane present | 0 segments | 12 | 0% (constant) |
| Bus bay present | 0 segments | 12 | 0% (constant) |
| Major junction present | Yes = 2 segments, No = 10 segments | 12 | 16.7% present, 83.3% absent |

### 3.2. Crash Concentration and Blackspot Identification

A total of 115 crashes (27 Fatal, 50 Serious Injuries, 38 Slight Injuries) were recorded over the study period. The mean crash frequency across segments was *9.58*.

Segments exceeding the average crash frequency were identified as blackspots:

1) Segment 11 (Kidanemihret roundabout): recorded the highest crash frequency (CF=36, WSI=73), accounting for 31.3% of total corridor crashes.
2) Segment 3: Recorded CF=20 (WSI=41).
3) Segment 2: Recorded CF=15 (WSI=26).
4) Segment 1: Recorded CF=11 (WSI=26).

### 3.3. Statistical Modelling

#### 3.3.1. Correlation Analysis

Pearson correlation revealed a strong, statistically significant relationship between the presence of Major Junctions and Weighted Severity Index ($r=0.688$, $p=0.013$). Walkways and Number of lanes exhibited perfect collinearity ($r=1.000$, $p<0.001$), as walkways were only provided on the 4-lane sections.

#### 3.3.2. Multiple Linear Regression Model

A multiple linear regression model was built using Major junctions and Number of lanes as predictors for WSI:

$$WSI = 19.464 + 40.214\ (\text{Major junction}) - 3.393\ (\text{Number of lanes})$$

***Table 2.*** *Regression Model Summary.*

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .697[a] | 0.486 | 0.372 | 16.81281 |

***Table 3.*** *Regression Coefficients.*

| Model | | Unstandardized Coefficients | | Standardized Coefficients | t | Sig. | Collinearity Statistics | |
|---|---|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | | Tolerance | VIF |
| 1 | (Constant) | 19.464 | 16.51 | | 1.179 | 0.269 | | |
| | Major junction | 40.214 | 14.209 | 0.738 | 2.83 | 0.02 | 0.84 | 1.19 |
| | Number of lanes | -3.393 | 7.105 | -0.124 | -0.478 | 0.644 | 0.84 | 1.19 |

Key Finding: the presence of a major junction on a segment increases the weighted Severity Index by 40.21 points on average which indicates that junction redesign is the critical intervention for this corridor.

#### 3.3.3. Mann-Whitney U Non-Parametric Validation

Due to the small sample size ($N=12$), non-parametric tests confirmed a large effect size for major junctions ($r=-0.529$, $Z=-1.833$) and a moderate effect size for Walkway presence ($r=-0.374$, $Z=-1.294$).

### 3.4. Projected Safety Impact through Crash Modification Factors (CMFs)

Due to lack of variation in baseline data for bike lanes, bus bays, and lane widths, literature-based CMFs (from the FHWA Clearinghouse and AASHTO HSM) were used to project countermeasure performance:

*Table 4. Projected safety impact through Crash Modification Factors (CMFs).*

| Proposed Countermeasure | Applied CMF | Projected Crash Reduction | Target Crash Type | Source |
|---|---|---|---|---|
| Dedicated Bike Lanes (2m) | 0.68 | 32% | Vehicle-Bicycle Collisions | FHWA Clearinghouse [7, 9] |
| Continuous Walkways (5m) | 0.35 | 65% | Pedestrian-Vehicle Collisions | FHWA (ID: 1337) [8] |
| Right-turn geometry modification | 0.558 | 44% | Junction conflict | FHWA (ID: 8496) [11] |
| Left-turn/U-turn Prohibition | 0.32 | 68% | Angle and Head-On Collisions | AASHTO HSM [13] |

### 3.5. Specific Intervention: Kidanemihret Junction Redesign (Segment 11)

Segment 11 represents a high-risk location due to a steep gradient (~7%) combined with substandard roundabout. Heavy vehicles on steep downgrades face severe rollover hazards when negotiating circular cambers, alongside excessive braking demands [2].

*Redesign Strategy:* Reconfiguring the roundabout into a priority junction maintains a linear vertical profile for heavy vehicles, removing camber caused rollover risks while providing dedicated turning channels and optimized sight lines (CMF=0.558).

### 3.6. Stakeholder Perception Results

Targeted survey responses (N=22) among engineers, transport planners, drivers, vulnerable road users aligned with empirical findings:

1) *Primary Crash Causes:* Stakeholders overwhelmingly identified poor junction design, high vehicle speeds, forced mixed NMT-motorized traffic flow as the leading causes of severe crashes along the corridor [5].
2) *Safety Concerns:* Severe pedestrian-vehicle conflicts caused by lack of continuous walkways and dedicated bike lanes.
3) *Priority Measures:*
   a) *Continuous Walkway:* high support for 5m walkways (both side) to eliminate pedestrian walking in live travel lanes.
   b) *Junction Geometry Redesign:* Respondents favored reconfiguration of geometric design of the junction or signalized controls to manage heavy vehicle stability.
   c) *Dedicated Bus bays and Bike lanes:* strongly supported by road users and experts to reduce friction caused by informal public transport stops and low-speed non-motorized traffic.

## 4. Conclusions and Recommendations

### 4.1. Conclusions

1) Major junctions are the primary determinant of crash severity along the 18 Mazoria-Ashewa Meda corridor (B=40.214, p=0.02).
2) Vulnerable road users (VRUs) face extreme vulnerability due to 83.3% deficit in continuous walkways and 100% absence of cycling infrastructure.
3) Converting the Kidanemihret roundabout to priority junction with proper signage and marking expected to address the critical interaction between heavy vehicle dynamics and steep gradients (~7%) [1, 10].
4) The integration of continuous walkways, bike lanes, bus bays, and junction geometry modifications is projected to yield individual crash reductions ranging between 32% and 68%.

### 4.2. Recommendations

1) *Construction Quality and Maintenance:* Strict adherence to complete street design guidelines and routine maintenance of pavements, signs, markings and signals.
2) *Integrate Operational Measures:* combine physical upgrades with public education, strict enforcement, and speed management [12].
3) *Conduct Before-After Studies:* Evaluate post-implementation safety performance to validate CMF projections, develop local CMFs and measure individual and combined intervention impacts [6].
4) *Track Longitudinal Impacts:* Monitor long-term safety trends to observe how benefits evolve with user adaptation and rising traffic volumes.
5) *Strengthen Data Management:* Partner with key authorities (ERA, AACRA), to standardized crash reporting, build centralized databases and mandate regular road safety audits.

# Abbreviations

| | |
|---|---|
| AASTU | Addis Ababa Science and Technology University |
| AACRA | Addis Ababa City Roads Authority |
| AASHTO | American Association of State Highway and Transportation Officials |
| CF | Crash Frequency |
| CMF / CMFs | Crash Modification Factor / Crash Modification Factors |
| ERA | Ethiopian Roads Authority |
| FHWA | Federal Highway Administration |
| HSM | Highway Safety Manual |
| NCHRP | National Cooperative Highway Research Program |
| NMT | Non-Motorized Transport |
| SD | Standard Deviation |
| SPSS | Statistical Package for the Social Sciences |
| VIF | Variance Inflation Factor |
| VRU | Vulnerable Road User |
| WSI | Weighted Severity Index |

# Author Contributions

**Rehima Aman Bedewi:** Conceptualization, Resources, Data curation, Formal analysis, Investigation, Methodology, Software, Writing – original draft, Writing – review & editing

**Tefera Bahiru:** Supervision

# Conflicts of Interest

The authors declare no conflicts of interest.

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