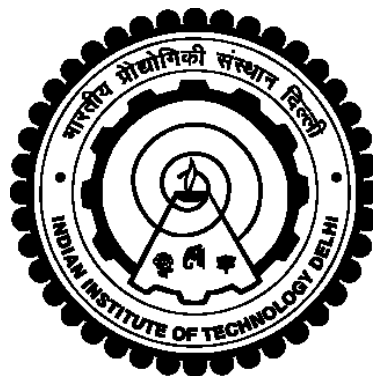


**ROAD SAFETY ASSESSMENTS OF MODERN TOLL  
PLAZAS AND STANDARDIZATION OF ITS  
GEOMETRIC DESIGN**

**NAVDEEP KUMAR ASIJA**



**DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY DELHI  
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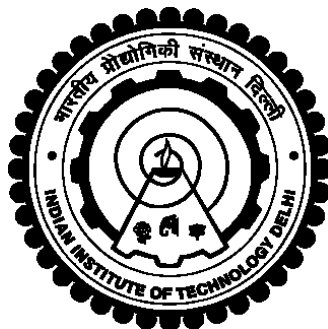
# **ROAD SAFETY ASSESSMENTS OF MODERN TOLL PLAZA AND STANDARDIZATION OF ITS GEOMETRIC DESIGN**

by

**Navdeep Kumar Asija**  
**Department of Civil Engineering**

Submitted

In fulfillment of the requirements of the degree of Doctor of Philosophy  
to the



**INDIAN INSTITUTE OF TECHNOLOGY DELHI**  
**OCTOBER 2019**

## **Certificate**

This is to certify that the thesis entitled *“Road Safety Assessments of Modern Toll plazas and Standardization of its Geometric Design”* submitted by **Mr. Navdeep Kumar Asija** to the **Indian Institute of Technology Delhi**, India for the award of the degree of **Doctor of Philosophy**, is a record original bona fide research work carried out by him. Navdeep has worked under my guidance and supervision. To the best of my knowledge, the thesis has met the requisite standards. The material contained in this thesis has not been submitted, in part or in full, to any other university or institute for the award of any degree or diploma.

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**Place: New Delhi**

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**Navdeep K. Asija**

## **Abstract**

The single element which distinguishes a toll facility from a publicly financed road, bridge, or tunnel is a toll plaza. The toll plaza is defined as the area where tolls are collected using different methods. With the introduction of electronic toll collection (ETC), management and surveillance technologies at the traditional toll plaza, it has been termed as Modern Toll plaza. National Transport Safety Board 2006, USA, noted that no scientific toll plaza design standards exist till date. The only standards are those developed by individual toll operators, based on their years of experience through improvements or expansion of their facilities. There is a clear-cut conflict between effective management vs. safety performance. The present Indian Roads Congress guidelines to design toll plazas in India are based on the operational efficiency standards, i.e. service time at a toll plaza, which means, more the traffic, greater the number of toll lanes.

A literature review revealed that three main toll plaza design standards available in USA, UK, and India are the compiled wisdom of the best practices being followed by different toll agencies globally without any rational method of diagnosing or designing using road safety as one of the variables. Introduction and use of electronic toll collection (ETC) are two decades old (Ding and Xiang 2004), but a few recent studies have reported that use of ETC with manual lane have an impact on road safety. Another important study by Abdelwahab and Abdel-Aty also established that modern toll plaza does contribute to road accidents.

The present study identifies significant contributory factors to traffic crashes at modern toll plaza areas in India based on crash incidences and traffic volume at the toll plaza areas of 14 tolled roads, covering various State and National Highways. Data was obtained from the traffic accident database system and annual traffic census from the concerned toll operators and police departments for the period between years 2013 to 2015. This data together with the geometric and operational characteristics, including a number of toll plaza lanes and

length of the toll plaza, carriageway width, classified traffic volume and annual average daily traffic (AADT), were incorporated into safety performance function for different traffic directions of toll plaza areas vs. rest of the road corridor. Different probability distribution models, like Poisson and Negative Binomial (NB), are discussed and after checking over dispersion, mean versus variance criteria, a final Negative Binomial distribution model is selected to develop a Safety Performance Function (SPF).

A total 4,600 road crashes cases, including 450 fatal, 617 non-fatal and 3,565 minor crashes, were studied for modeling, covering the 346.55 km length of various types of highways having toll plazas with different lane configuration varying from four lanes to 32 lanes. Considering Poisson, Negative Binomial and Zero-Inflated Negative Binomial, due to over dispersion and difference between mean and variance, finally, a safety performance function using negative binomial distribution function has been developed to predict the average number of crashes per year at a toll plaza location as a function of traffic and width of the toll plaza. The predicted number of crashes at toll plaza calculated using SPF will be used as an instrument for better design configuration selection or the comparison or checking between two or more toll plazas as well. The study concludes that the probability of crash at toll plaza increases by adding a number of lanes beyond optimum numbers via overall increased width and length of toll plazas. The study includes analysis on approach zone crashes vs. exit zone crashes, their types, and victim group. Approach zones of all the large size toll plazas and user wise non-tollable traffic, like pedestrians, cyclists, and two-wheelers, are found to be the most vulnerable.

Further, the revised suggestive guidelines for the modern toll plaza for Indian conditions have been developed with Safety performance function, including the guidelines developed for entry and exit zone lengths, length of the toll plaza and width of the toll plazas. This part is based upon the existing Indian Roads Congress guidelines.

## संक्षेप

टोल प्लाज़ा किसी भी सड़क का इकलौता प्रमुख भाग होता है जो सार्वजनिक सड़क, पुल या सुरंग को टोल सड़क से अलग करता है। टोल प्लाज़ा को अगर परिभाषित करना हो तो उस नियोजित स्थान को कहा जा सकता है जहाँ पर भिन्न-भिन्न तरीकों से टोल फ़ीस को संगृहीत किया जाता है। टोल प्लाज़ा पर इलेक्ट्रॉनिक टोल संग्रह (ETC - विद्युत संचालित टोल संग्रह) व अन्य प्रबंधन व निगरानी सम्बन्धिक तकनीकों के परम्परागत इस्तेमाल के बाद इन्हें मॉडर्न (आधुनिक) टोल प्लाज़ा भी कहा जाने लगा है। अमरीकी नेशनल ट्रांसपोर्ट सेफ्टी बोर्ड ने वर्ष 2006 में ये टिप्पणी की और माना की आधुनिक टोल प्लाज़ा के डिज़ाइन के वैज्ञानिक मापदंड आज तक तय नहीं किये गए हैं। ज्यादातर मापदंड जो प्रचलित हैं वे या तो खुद वैयक्तिक टोल आपरेटर द्वारा बनाये गए हैं, जो उनके तजुर्बे व उनके द्वारा प्रायोजित सुविधाओं के विस्तार के लक्ष्य के आधार पर नियोजित किये जाते रहे हैं। एक तरफ इनके असरदार प्रबंधन व दूसरी तरफ इनके सुरक्षा प्रदर्शनों के बीच साफ़ व गहरा मतभेद मौजूद है। मौजूदा भारतीय रोड कांग्रेस के दिशा निर्देशों के अनुसार भारत में टोल प्लाज़ा के डिज़ाइन इनके परिचालन दक्षता मापदंड के आधार पर पालन किये जाते हैं, जैसे की टोल प्लाज़ा पर सर्विस टाइम जिसका मतलब है जितना ट्रैफिक उतना ही टोल लें ।

सम्बन्धित साहित्यिक समीक्षा से पता चलता है कि टोल प्लाज़ा को डिज़ाइन करने के जो तीन मानक हैं वो भारत, अमरीका व यूनाइटेड किंगडम में प्रचलित हैं, वे प्रचलित प्रथाओं के संकलित ज्ञान से उत्पन्न हुये हैं जो की विश्व के भिन्न टोल एजेन्सीयों के द्वारा बिना किसी तर्कसंगत पद्धति के, जो सड़क सुरक्षा या संरचनात्मक पहलुओं में से किसी एक को भी मापदंड के रूप में माप में ले , उनका पालन कर रही हैं। ETC ( इलेक्ट्रॉनिक टोल कलेक्शन -विद्युत संचालित टोल संग्रह ) को आरम्भ हुए दो दशक से ज़्यादा बीत चुके हैं, परन्तु कुछ ही हाल में हुए अध्ययन से पता चलता है के ETC का इस्तेमाल दस्त कार्यकारी पथ पर, सड़क सुरक्षा पर असर होता है। हाल ही के अध्ययन से ये भी साबित होता है के आधुनिक टोल प्लाज़ा सड़क हादसों में योगदान करते हैं।

यह अध्ययन आधुनिक टोल प्लाज़ा पर यातायात दुर्घटनाओं के कारणों को चिन्हित करती हैं और इसका आधार है 14 राज्य व राष्ट्रीय राजमार्ग पर स्थित टोल प्लाज़ा पर दर्ज हुई दुर्घटनाओं व यातायात संख्या हैं। इस अध्ययन के लिए सन 2013 से 2015 के आंकड़ों को लिया गया और उसी के अनुसार अध्ययन किया गया है, जो की सड़क दुर्घटना आंकड़ों के आधार व वार्षिक यातायात गणना पर आधारित हैं , जो की संबंधित टोल ऑपरेटरों व पुलिस विभाग से प्राप्त की गई हैं । आंकड़ों के आधार के साथ में ज्यामितीय व परिचालन लक्षण, जिसमें शामिल हैं टोल प्लाजा पर टोल पथ संख्या, टोल प्लाजा की लंबाई, वाहक पथ की चौड़ाई, वर्गीकृत यातायात संख्या और वार्षिक औसत दैनिक यातायात (AADT), ये सभी कारक शामिल किए गए हैं। टोल प्लाजा के मुकाबले बाकी सड़कों पर सुरक्षा प्रदर्शन मानकों को आध्यान में शामिल किया गया है । सुरक्षा प्रदर्शन अंग को विकसित करने में, अलग संभावित वितरण माडल जैसे के प्वाइजन अथवा नकारात्मक द्विपद (Poisson and Negative Binomial), को चर्चा का हिस्सा बनाया गया है और अति फैलाव का अनुमान लिये जाने पर, अंतिम नकारात्मक द्विपद वितरण (Negative Binomial Distribution) माडल विकसित किया गया है।

माडलिंग के लिए कुल 4,600 सड़क दुर्घटनाओं के मामले, जिनमें 450 घातक, 617 गैर-घातक और 3,565 मामूली दुर्घटनाएं शामिल हैं, का अध्ययन किया गया है । इसमें 346.55 किमी लंबाई के विभिन्न प्रकार के टोल राजमार्ग शामिल किये गए हैं, जिन पर चार लेन से लेकर 32 लेन तक विभिन्न लेन विन्यास वाले टोल प्लाज़ा स्थापित हैं। अतिउत्पादन और मीन और विचरण के बीच अंतर के कारण पॉइसन, नकारात्मक द्विपद और शून्य-सूजन नकारात्मक द्विपद को ध्यान में रखते हुए, आखिरकार, एक टोल प्लाजा पर प्रति वर्ष दुर्घटनाओं की औसत संख्या की भविष्यवाणी करने के लिए नकारात्मक द्विपद वितरण का उपयोग करते हुए एक सुरक्षा प्रदर्शन अंग (SPF) विकसित किया गया है। एसपीएफ में यातायात और टोल प्लाजा की चौड़ाई के एक समारोह के रूप में उपयोग करके आधुनिक टोल प्लाजा पर दुर्घटनाओं की अनुमानित संख्या का गणना या बेहतर

आधुनिक टोल प्लाज़ा डिज़ाइन विन्यास चयन दो या अधिक टोल प्लाज़ा के बीच सड़क सुरक्षा तुलना या जाँच के लिए एक उपकरण के रूप में किया जा सकेगा | अध्ययन का निष्कर्ष ये है कि बड़े आधुनिक टोल प्लाज़ा पर एक दुर्घटना की संभावना कुल वृद्धि चौड़ाई और इष्टतम संख्या से अधिक टोल गलियों को जोड़कर बढ़ जाती हैं। अध्ययन में दृष्टिकोण पर विश्लेषण, प्रवेश क्षेत्र दुर्घटना बनाम निकास क्षेत्र दुर्घटना, उनके प्रकार और पीड़ित समूह शामिल हैं। अध्ययन में यह भी पाया गया की सभी बड़े आकार के आधुनिक टोल प्लाज़ा गैर-टोल यातायात उपयोग कर्ता जैसे की पैदल यात्री, साइकिल चालक और दोपहिया वाहन के दृष्टिकोण क्षेत्र में सबसे कमजोर पाए गए हैं |

इसके अलावा, भारतीय परिस्थितियों के लिए आधुनिक टोल प्लाज़ा के लिए संशोधित सुझाव दिशानिर्देश सुरक्षा प्रदर्शन अंग (SPF) के साथ विकसित किए गए हैं, जिसमें टोल प्लाज़ा के प्रवेश और निकास क्षेत्र की लंबाई, टोल प्लाज़ा की चौड़ाई और टोल प्लाज़ा की कुल लंबाई के लिए विकसित दिशानिर्देश शामिल हैं। यह हिस्सा मौजूदा भारतीय सड़क कांग्रेस के दिशानिर्देश पर आधारित हैं।

# Table of Contents

Certificate.....	i
Acknowledgments.....	ii
Abstract.....	vi
संक्षेप.....	viii
Table of Contents.....	xi
List of Figures.....	xvi
List of Tables .....	xviii
List of Acronyms .....	xxiii
<b>1. Introduction .....</b>	<b>1</b>
1.1. General .....	1
1.2. Modern Toll Plaza .....	1
1.3. Methods of Tolling .....	3
1.4. Type of Toll Plazas.....	3
1.5. Toll collection systems .....	4
1.5.1. Manual Toll Fee Collection Approach.....	4
1.5.2. The Automatic or Semi-Automatic Approach .....	4
1.5.3. The Electronic Toll Fee Collection .....	5
1.6. Modern Toll Plaza Scenario in India and other Developing Countries .....	6
1.7. International Scenario and Modern Toll Plaza Design Standards.....	6
1.7.1. United States of America .....	6
1.7.2. United Kingdom.....	6
1.7.3. India .....	7

1.8.	<i>Road Transportation Sector and Toll Roads Growth in India</i> .....	7
1.9.	<i>Aim and Scope of the Research</i> .....	8
1.10.	<i>Objectives of the Research</i> .....	9
1.11.	<i>Research Study Area</i> .....	9
1.11.1.	Summary of design and operational features of toll plazas selected for this study: .....	14
1.12.	<i>Important Definitions</i> .....	14
1.13.	<i>Structure of the Thesis</i> .....	17
<b>2.</b>	<b>Literature Review</b> .....	<b>18</b>
2.1.	<i>Toll Roads and Toll Plaza</i> .....	18
2.2.	<i>Initial Research on Modern Toll Plaza and its Design</i> .....	18
2.3.	<i>Operational Efficiency at Modern Toll Plaza</i> .....	19
2.4.	<i>Road Safety and Modern Toll Plaza</i> .....	20
2.5.	<i>National and International Code of Practices for the Designing of Modern Toll Plaza</i> .....	24
2.5.1.	India .....	24
2.5.2.	United Kingdom.....	26
2.5.3.	United States of America (USA) .....	26
2.6.	<i>Conclusions</i> .....	27
2.7.	<i>Gap in Research</i> .....	29
<b>3.</b>	<b>Research Methodology</b> .....	<b>31</b>
3.1.	<i>General</i> .....	31
3.2.	<i>Data Collection</i> .....	31
3.3.	<i>Limitation of Road Crash Data: Only Fatal Road Crashes for Statistical Modeling</i> .....	33
3.3.1.	Objective 1: To perform road safety assessment at Modern Toll Plaza on overall road safety of the corridor .....	35
3.3.2.	Objective 2: To develop Safety Performance Function (SPF <sub>T</sub> ) and design guidelines for Modern Toll Plaza in Indian scenario .....	38
3.4.	<i>Recommendations and Final Design Guidelines</i> .....	39

<b>4</b>	<b>Data Collection.....</b>	<b>40</b>
4.1	<i>Study Area.....</i>	40
4.1.1	Optimal Crash Duration for Addressing Road Safety Issues.....	40
4.1.2	Toll Road and Toll Plaza Codes .....	40
4.1.3	Data Collection and Sources .....	43
	<i>Toll road corridor wise details of each road are summarized in the next section.....</i>	46
4.2.1	Project Details.....	47
4.2.2	Balachaur- Garhshankar (S01).....	47
4.2.3	Garhshankar-Hoshiarpur Section (S01).....	48
4.2.4	Hoshiarpur-Dasuya Section (S01) .....	49
4.3	<i>Dakha –Rajkot-Barnala (S02) .....</i>	50
4.3.1	Project Details.....	50
4.3.2	Dakha –Rajkot Section (S02).....	50
4.3.3	Rajkot-Barnala Section (S02) .....	51
4.4	<i>Patiala Samana Patran SH-10 (S03).....</i>	52
4.4.1	Project Details.....	52
4.5	<i>Kiratpur Sahib-Anandpur Sahib-Himachal Border (SH04) .....</i>	53
4.5.1	Project Details.....	53
4.6	<i>Morinda-Kurali-Siswan MDR-31 from km 0+00 to km 29+66 (M05).....</i>	55
4.6.1	Project Details.....	55
4.7	<i>NH-21(New NH 205) Kurali-Kiratpur Section km 28+600 to km 73+200.....</i>	57
4.7.1	Project Details.....	57
4.8	<i>NH-22 Ambala Zirakpur Section km 5+735 to km 39+960 (N07) .....</i>	59
4.8.1	Project Details.....	59
4.9	<i>Delhi-Gurgaon Expressway NH-8 (N08).....</i>	61
4.9.1	Project Details.....	61
4.10	<i>Zirakpur- Parwanoo section of NH-5 (old NH-22) (N09) .....</i>	64
4.10.1	Project Details.....	64
4.11	<i>Panipat Elevated Highway NH-1 (N10)- New NH-44 .....</i>	66
4.11.1	Project Details.....	66

4.12	<i>Summary of Road Traffic Crash Patterns at Toll Plazas</i> .....	70
<b>5</b>	<b>Road Safety Assessment and Development of Safety Performance Function for Modern Toll Plaza</b> .....	<b>71</b>
5.1	<i>Why Only Fatalities</i> .....	71
5.2	<i>Road Safety Assessment of Toll Plazas</i> .....	72
5.2.1	To Perform Road Safety Assessment of Modern Toll Plaza w.r.t Overall Road Safety of the Corridor.....	72
5.3	<i>Hypothesis 2: Large Size Toll Plazas Contribute to More Crashes</i> .....	79
5.3.1	The paired t-test on Small Toll Plazas situated on State Highways and Major District Road having toll lanes $\leq 10$ (50m width).....	79
5.3.2	Overall Conclusion from Paired t-test on Two Different Toll Plaza Groups.....	81
5.4	<i>Hypothesis 3: Which Zone of Toll Plaza Contributes More Crashes: Approach Zone versus Exit Zone of Toll Plaza</i> .....	82
5.4.1	Which Zone of the Toll Plaza Contributes Number of Crashes.....	82
5.4.2	Important Observations from Road Safety Assessment Data Analysis .....	88
5.5	<i>Development of Safety Performance Function (<math>SPF_T</math>) for Modern Toll Plaza</i> .....	89
5.5.1	Selection of Statistical Model .....	89
5.5.2	Poisson and Negative Binomial (NB).....	90
5.5.3	Selection of Variable to Represent Traffic in $SPF_T$ .....	91
5.5.4	Development of $SPF_T$ using AADT as Variable to Represent Traffic.....	94
5.5.5	Discussion of Zero-Inflated Models.....	97
5.5.6	Validation for suitability of Negative Binomial (NB) and Zero-Inflated Negative Binomial (ZINB) for $SPF_T$ .....	98
5.6	<i>Discussion on the Results</i> .....	99
<b>6</b>	<b>Modern Toll/Fee Plaza Design Standards for India</b> .....	<b>101</b>
6.1	<i>General – Revision of Indian Roads Congress Standards</i> .....	101
6.2	<i>Design Method of Toll/Fee Plaza Design</i> .....	101
6.3	<i>Number of Toll Lanes</i> .....	103
6.4	<i>The Width of Toll Lane</i> .....	103

6.5	<i>The Width of Toll Plaza (<math>W_T</math>)</i> .....	103
6.6	<i>Toll Plaza Lanes Configuration</i> .....	104
6.6.1	Safety Performance Function for Toll Plaza ( $SPF_T$ ).....	104
6.6.2	Waiting Time and Number of Toll Lanes.....	104
6.7	<i>Length of the Toll Plaza</i> .....	107
6.7.1	Approach Zone and Exit Zone Transitional Length.....	107
6.7.1.1	Approach Taper ( $L_{AT}$ ).....	107
6.7.1.2	Departure Taper ( $L_{DT}$ ).....	108
6.8	<i>Toll Plaza Design Example</i> .....	110
<b>7</b>	<b>Results and Conclusions</b> .....	<b>113</b>
7.1	<i>Results and Discussion</i> .....	113
7.2	<i>Scientific Contribution</i> .....	113
7.3	<i>Future Research Work</i> .....	114
	<b>References</b> .....	<b>115</b>
	<b>Author's Brief Bio-data</b> .....	<b>120</b>

## List of Figures

Figure 1-1: Toll Plaza Elements-Plan View .....	2
Figure 1-2: Conflicting Traffic Movement at the Approach Transition Zone of Toll Plaza .....	3
Figure 1-3 : Showing the list of Toll plazas with different toll lane configuration under study .....	10
Figure 1-4 : Index map of toll roads and toll plazas under study .....	13
Figure 3-1 : Stages of Research Methodology .....	34
Figure 4-1: View of 10 Lane toll plazas at Km 14.5 village Baraudi .....	55
Figure 4-2 : View of the Toll Plaza on NH-21 at Behrampur Km 35+000 .....	57
Figure 4-3: Chart showing Entry and Exit Zone Road Crashes at Toll plaza on NH-21 (N-6/1) .....	58
Figure 4-4 : Details of Toll Plaza on NH-22.....	59
Figure 4-5: Chart showing Entry and Exit Zone Road Crashes at Toll plaza on NH-21 (N07/1).....	60
Figure 4-6: View of Rajokri Toll Plaza on Delhi Gurgaon Expressway NH-08 (N08/2) .....	61
Figure 4-7: Chart showing Entry & Exit Zone Road Crashes at Toll Plaza on NH-8 (N08/1) Km 42+00 .....	62
Figure 4-8: Chart showing Entry & Exit Zone Road Crashes at Toll Plaza at Km 24+00 on NH-8 (N08/2).....	63
Figure 4-9: View of Chandi Mandir Toll Plaza at NH-22 (N09/1) at Km 51+400 .....	64
Figure 4-10: Chart showing Entry & Exit Zone Road Crashes at Toll Plaza at Km 51+400 on NH-22 (N09/1).....	65
Figure 4-11: View of Panipat Elevated Road Toll plaza at NH-1 (New NH-44).....	66
Figure 4-12: Chart showing Entry & Exit Zone Road Crashes at Toll plaza at Km 95+00 on NH-01 (N10/1).....	67
Figure 5-1: Identification of Road Safety Assessment at Modern Toll plaza (Analysis).....	72
Figure 5-2: Crash Rate for Fatal crashes at Toll Plazas versus Corridor.....	76
Figure 5-3: Entry Zone versus Exit Zone Crash on all six National Highways Toll Plaza .....	83
Figure 5-4: Type of Fatal Crashes at Toll Plaza in Approach and Exit Zone.....	85
Figure 5-5 : Process Chart for the Development of $SPF_T$ .....	89

Figure 6-1: Process Chart to Design Modern Toll Plaza .....	102
Figure 6-3: Merging Points and Conflicting Lanes .....	106
Figure 6-4: Average Time Wasted (Cherng, Lewis, & Pai 2005) .....	107
Figure 6-2: Width of Toll Plaza and Offset Width of Toll plaza.....	108
Figure 6-5: 20 Lane Toll Plaza with Traditional Design Approach and for Same AADT Splitter Plaza with 10-10 Lane using $SPF_T$ .....	112

## List of Tables

Table 1-1: List of Toll Roads and Toll Plazas Selected for the Study.....	11
Table 2-1: Toll Plaza Level of Service Criteria .....	20
Table 2-2: Number of toll lanes in each direction (Semi-Automatic toll gates).....	24
Table 2-3: Capacity of Toll Lane for Two-Lane road toll plazas .....	25
Table 3-1 : Types of Data collected.....	31
Table 3-2: Relationship between P and $\chi^2$ .....	36
Table 4-1: List of Toll Roads under study, Toll Plazas, their Lengths and Number of Lanes	41
Table 4-2: Summary of Primary and Secondary Sources of Data along with Details of Field Studies.....	43
Table 4-3: Details of different types of data variables and its source for different State Highway and Major District Road under study .....	44
Table 4-4: Details of different types of data variables and its source for different National Highways under study.....	45
Table 4-5: Details of the Balachaur- Garshankar-Hoshiarpur-Dasuya Road Section .....	47
Table 4-6: Details of Toll plaza (SH01/1) on between Balachaur and Garshankar section of S01 Toll road on SH-24 .....	47
Table 4-7: Tollable AADT based upon the year 2015 at Toll plaza (SH01/1) on between Balachaur and Garshankar section of S01 Toll road on SH-24 .....	48
Table 4-8 : Details of Toll plaza crashes for the Balachaur and Garshankar section of on SH-24 (SH01) of the road for the period between January 2013 to December 2015 .....	48
Table 4-9: Details of Toll Plaza (SH01/2) on between Garshankar and Hoshiarpur section of S01 Toll road on SH-24 .....	48
Table 4-10: Tollable AADT based upon the year 2015 at Toll Plaza (SH01/2) on between Garshankar and Hoshiarpur section of S01 Toll road on SH-24 .....	48
Table 4-11: Details of Toll plaza crashes as at Toll Plaza S01/2 follow; .....	49
Table 4-12: Details of Toll Plaza (SH01/3) on between Hoshiarpur to Dasuya section of S01 Toll road on SH-24 .....	49
Table 4-13: Tollable AADT based upon the year 2015 at Toll Plaza (SH01/3) on between Hoshiarpur to Dasuya section of S01 Toll road on SH-24 .....	49

Table 4-14: Details of Toll Plaza crashes as at Toll Plaza S01/3 follow.....	49
Table 4-15: Section details of Dakha –Rajkot-Barnala (SH-13) .....	50
Table 4-16: Details of Toll plaza (SH02/1) on between Dakha to Rajkot section of S02 Toll road on SH-24.....	50
Table 4-17: Tollable AADT based upon the year 2015 at Toll Plaza (SH02/1) on between Dakha to Rajkot section of S02 Toll road on SH-24 .....	50
Table 4-18: Details of Toll Plaza crashes as at Toll Plaza S02/1 between Dakha-Rajkot sections of the S02 Toll road (SH-24) for the period between January 2013 to December 2015.....	51
Table 4-19: Details of Toll Plaza (SH02/2) on between Rajkot to Barnala section of S02 Toll road on SH-24.....	51
Table 4-20: Tollable AADT based upon the year 2015 at Toll Plaza (SH02/2) on between Rajkot to Barnala section of S02 Toll road on SH-24 .....	51
Table 4-21: Details of Toll Plaza crashes as at Toll Plaza S02/1 between Rajkot Barnala sections of the S02 Toll road (SH-24) for the period between January 2013 to December 2015 .....	51
Table 4-22: Section details of Patiala-Patran-Samana Road (SH-10).....	52
Table 4-23: Details of Toll Plaza on Patiala Samana Patran SH-10.....	52
Table 4-24: Tollable AADT based upon the year 2015 on Toll plaza on Patiala Samana Patran SH-10.....	53
Table 4-25: Details of the toll road and toll plaza crashes at Km 90+250 Asarpur Chupki on SH-10 for the period between January 2013 to December 2015 as follows.....	53
Table 4-26: Details of Toll Plaza on Kirapur Sahib-Anandpur Sahib-Himachal Border (SH04) .....	54
Table 4-27: Tollable AADT based upon the year 2015.....	54
Table 4-28: Details of the toll road and toll plaza crashes at Km 32.50 Kotla Nakkian on SH-25 for the period between January 2013 December 2015.....	54
Table 4-29: Details of Toll Plaza on Morinda-Kurali-Siswan MDR-31 .....	56
Table 4-30: Tollable AADT based upon the year 2015.....	56
Table 4-31: Details of the toll road and toll plaza crashes at Km 14.5 village Baraudi for the period between January 2013 December 2015 .....	56

Table 4-32: Details of Toll Plaza on NH-21 (Kurali-Kiratpur Section) .....	58
Table 4-33: Classified AADT Behrampur Toll Plaza at Km 35+000 on NH-21 Kurali-Kiratpur Section N06/1 for the Year 2015.....	58
Table 4-34: Summary of Total Crashes vs. Toll Plaza Crashes at Kurali Kiratpur section of NH-21 for the period between January 2013 to December 2015 .....	58
Table 4-35: Details of Toll Plaza on NH-22 (Ambala Zirakpur Section).....	60
Table 4-36: Classified AADT Km 23+080 on NH-22 Ambala Zirakpur Section N07/1 for the year 2015.....	60
Table 4-37: Summary of Total Crashes vs. Toll Plaza Crashes for section Ambala Zirakpur Section of NH-21 between the periods January 2013 to December 2015 .....	60
Table 4-38: Details of Toll Plazas on Delhi –Gurgaon Expressway on NH-8 .....	62
Table 4-39: Classified AADT for Delhi Gurgaon Expressway NH-08 (N08) at Kherki Daula Toll Plaza (N08/1) at NH-8 at Km 42+00 .....	62
Table 4-40: Details of the toll road and toll plaza crash At Km 42+000, near village Kherki Daula (N08/1) for the period between January 2013 to December 2015 .....	62
Table 4-41: Classified AADT for Delhi-Gurgaon Expressway NH-08 (N08) at Km 24+000 near Rajokri Toll Plaza (N08/2).....	63
Table 4-42: Details of the toll road and 32 lane toll plaza crashes At Km 24+000, near Rajokri (N08/2) for the period between January 2013 to December 2015.....	63
Table 4-43: Details of Toll Plaza on NH-22 (N09/1) near Chandimandir .....	65
Table 4-44: Classified AADT for Himalayan Expressway NH-22 (N09) at Chandi Mandir Toll Plaza N10/1 .....	65
Table 4-45: Summary of Total Crashes vs. Toll Plaza Crashes from January 2013 to December 2015 at Parwanoo, Km 51+400 Toll Plaza.....	65
Table 4-46: Details of Toll Plaza on NH-1 (N10/1) on Panipat Elevated Highway.....	66
Table 4-47: Classified AADT for Panipat Elevated Road and Including Tollable Traffic at Toll Plaza N10/1 for the year 2015.....	67
Table 4-48: Details of the Toll road and Toll plaza (N10/1) crashes at Panipat Elevated Highway (NH-1) for the period between January 2013 to December 2015 .....	67
Table 4-49: Summary of Road Crashes at Toll Roads and Toll Plaza under Study.....	68
Table 4-50: Comparison of the fatal crash rate per kilometer .....	70

Table 5-1: Crash Rate at Toll Plaza vs. Crash Rate at Rest of the Corridor for State Highways -MDR and National Highways .....	74
Table 5-2: $\chi^2$ chi-square test result for statistical significance at 5%.....	77
Table 5-3: Crash Rate on Small Size Toll plaza on State Highways and Major District Roads .....	79
Table 5-4: Result of paired student t-test performed on small toll plazas situated on State Highways and Major District Roads.....	80
Table 5-5: Crash Rate on Large Size Toll plaza situated on National Highways.....	80
Table 5-6: Result of paired student t-test performed on large size toll plazas situated on National Highways.....	81
Table 5-7: Number of Fatal, Non-Fatal and Minor Crash Occurred in Different Zones of Toll Plazas under Study.....	82
Table 5-8: Summary of Total Approach Zone vs. Exit Zone Crashes on Six NH Toll Plazas	84
Table 5-9: paired t-test results on approach zone versus exit zone toll plaza fatal crashes .....	84
Table 5-10: Fatal Crash shared in Approach Zone and Exit Zones of Toll Plaza .....	85
Table 5-11: Different Type of Fatal Road Crashes in Approach Zone of Toll Plaza .....	86
Table 5-12: Different Type of Fatal Road Crashes in Exit Zone of Toll Plaza .....	86
Table 5-13: Collision Matrix of all Impacting Vehicles versus Victim Vehicle Involved in Fatal Road Crashes at Toll Plaza Areas .....	87
Table 5-14: Descriptive Statistics of Toll Plazas' Variables .....	90
Table 5-15: Toll Plaza Data with All Variables including Six Classified Categories of Tollable Traffic .....	92
Table 5-16 : Toll Plaza Data with Grouped Traffic Categories into Small, Medium and Large .....	93
Table 5-17: Measures of Fit test for Negative Binomial Using STATA for Light, Medium and Heavy Vehicle Classification System .....	94
Table 5-18 : Toll Plaza Data with AADT .....	95
Table 5-19 : Measures of Fit test for Negative Binomial using STATA with AADT.....	95
Table 5-20: Values of Log-Likelihood and Pseudo R2 for different variables using for Negative Binomial .....	96

Table 5-21: Measures of Fit test for Negative Binomial using STATA with Width of Toll Plaza and AADT .....	97
Table 5-22: Measures of Fit test for Negative Binomial using STATA.....	99
Table 5-23: Measures of Fit for Zero-Inflated Negative Binomial using STATA .....	99
Table 5-24: Comparison of AIC and BIC Values to Select between NB and ZINB for SPF of Toll Plaza .....	99
Table 6-1: Technology wise lane throughput capacity .....	103

## **List of Acronyms**

AADT	Annual Average Daily Traffic
ADT	Average Daily Traffic
AVI	Automatic Vehicle Identification
BOT	Built Operate Transfer
DMRB	Design Manual for Roads and Bridges
ETC	Electronic Toll Collection
FHWA	Federal Highway Administration
IRC	Indian Roads Congress
ITS	Intelligent Transport System
LCV	Light Commercial Vehicle
LOS	Level of Service
MAV	Multi Axle Vehicle
MDR	Major District Road
MoRTH	Ministry of Road Transport and Highways, Government of India
NH	National Highway
NB	Negative Binomial
NHAI	National Highways Authority of India
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board, USA
ODR	Other District Road
PIDB	Punjab Infrastructure Development Board
PWD	Public Works Department
RFID	Radio-Frequency Identification
SH	State Highway
ZINB	Zero Inflated Negative Binomial