

**USER PERCEPTION BASED PERFORMANCE  
EVALUATION OF INTERMEDIATE PUBLIC  
TRANSPORT SYSTEM IN SMALL CITY:  
CASE STUDY WARDHA, MAHARASHTRA, INDIA**

**AISHWARYA JAISWAL**



**DEPARTMENT OF CIVIL ENGINEERING  
INDIAN INSTITUTE OF TECHNOLOGY DELHI.**

**July 2025**

© **Indian Institute of Technology Delhi (IITD), New Delhi, 2025**

**USER PERCEPTION BASED PERFORMANCE  
EVALUATION OF INTERMEDIATE PUBLIC  
TRANSPORT SYSTEM IN SMALL CITY:  
CASE STUDY WARDHA, MAHARASHTRA, INDIA**

*by*

**AISHWARYA JAISWAL**

**DEPARTMENT OF CIVIL ENGINEERING**

*submitted*

*in fulfillment of the requirements for the award of the degree of*

**DOCTOR OF PHILOSOPHY**

*to the*



**INDIAN INSTITUTE OF TECHNOLOGY DELHI**

**JULY 2025**

## CERTIFICATE

This is to certify that the thesis entitled “**User Perception Based Performance Evaluation of Intermediate Public Transport System in Small City: Case Study Wardha, Maharashtra, India**” is being submitted by **Mrs. Aishwarya Jaiswal** to the Indian Institute of Technology Delhi, for the award of the degree of **Doctor of Philosophy**. This is a record of the research work and is entirely carried out by her under our supervision and guidance. The research report presented in this thesis has not been submitted for the award of any other degree or diploma.

**Dr. Manoj M.**

Associate Professor  
Department of Civil Engineering  
Indian Institute of Technology Delhi  
New Delhi – 110016  
India

**Dr. Geetam Tiwari**

Professor Emeritus  
Transportation Research and Injury  
Prevention Centre  
Indian Institute of Technology Delhi  
New Delhi – 110016  
India

## ACKNOWLEDGEMENTS

This dissertation represents the conclusion of my Ph.D. journey, which resembled ascending a tall peak gradually, facing challenges, support, setbacks, and faith along the way. While the cover page of this thesis solely features my name, its completion was made possible through the encouragement, support, and effort of many individuals, including my supervisors, friends, well-wishers, and family members.

I am extremely grateful to the “Department of Civil Engineering, Indian Institute of Technology Delhi” for the opportunities, exposures and all financial supports during my studies.

First, and foremost, I would like to express my deep and sincere gratitude to my supervisors Dr. Manoj M. and Dr. Geetam Tiwari for their blessings, patient guidance, and tenacious encouragement during the planning and development of this research work. I thankfully acknowledge their careful efforts to improve the manuscripts without which this research work could not have been finished.

I wish to extend my sincere gratitude to my research committee comprising Dr. Nezamuddin, internal expert, Dr. Sourabh Paul, external expert, and Dr. B. J. Alappat, the chairman, for their invaluable contributions throughout my research journey. Special gratitude is owed to Dr. B. J. Alappat for his insightful feedback and unwavering encouragement, which propelled me to surpass my previous endeavors.

I also extend my thanks to the departmental staff of Civil Engineering Department for providing help at various stages of my work. I express my thanks to Mr. Randhir Jha, and Miss Hema Narang, Mr. Mahesh Gaur, Mr. Hari Chand from the Civil Engineering Department and Transportation Research and Injury Prevention Center (TRIPP-C) for their exceptional

assistance in administrative duties.

I am also thankful to my seniors and classmates, whose communication and mental support, through from near and far places, have been great source of inspiration. I owe special thanks to Rashmeet Kaur, who has been a constant support in my journey. I acknowledge the efforts taken by her in getting approvals from faculties and departments for me in my absence. I would like to thank my lab mates Mrs. Ranjana Soni, Mrs. Suman Dwivedi, Dr. Richa Ahuja for their company and unconditional support, without these people I wouldn't have enjoyed my PhD journey. Thanks for all the good memories that we share including birthday parties, success parties and all mini trips. I would like to express my gratitude to Dr. Puyabeet Sarangi and Dr. Chetan Doddamani for their guidance and support. I would also like to thank my roommates Priyanka Prashar and Snigdha Mishra, with whom I enjoyed my home away from home. These two were always there for me in all the ups and down of my PhD journey. I am thankful to Purnima Bali for her distant support.

On top of that, I am deeply and thoroughly indebted to my parents and in-laws to all the freedom they have given to my choice of career and lifestyle. I express deep gratitude to my beloved father, late Shri. Sanjay R Jaiswal, who remains my ultimate source of inspiration and motivation. Every endeavor of mine is dedicated to his memory. Additionally, I acknowledge the influence of my late grandfather Shri Radheyshyamji Jaiswal, whose relentless pursuit of knowledge continues to inspire me. His embodiment of truth, dedication, and honesty serves as a guiding light in my life. A special thanks to my mother Mrs. Aradhana Sanjay Jaiswal for her support, motivation and trust in me, which helped me aim higher from time to time. I would also like to thank my sister, Miss Ayushi Jaiswal for being a constant source of inspiration and support for all possible help during all stages of this Ph.D. I am especially grateful to my uncles Mr. Rajendra Jaiswal and Mr. Manish Jaiswal for their support and encouragement during this work. Without their support collecting data from Wardha

Municipal corporation and conducting household surveys in Wardha city would have been impossible.

I owe thanks to a very special person, my husband, Dr. Yash Jaiswal for his continued and unfailing love, support and understanding during my pursuit of Ph.D. work that made the completion of thesis possible. You were always around at times I thought that it is impossible to continue, you helped me to keep things in perspective. I greatly value his contribution and deeply appreciate his belief in me.

I offer my regards and blessings to all of those who supported me in any respect during the completion of this thesis.

And last but not the least; I am always thankful to the omnipresent, GOD. Thank you all.

**AISHWARYA JAISWAL**

**New Delhi.**

## **ABSTRACT**

Urbanization is a worldwide phenomenon that has led to increased mobility demands. As urban areas continue to expand, there is an increasing need for sustainable, efficient, and user-centric transportation solutions. Intermediate public transit (IPT) plays a pivotal role in the mobility framework of developing countries. Indian cities, portrayed by rapid urbanization and growing population, often face unique challenges in providing efficient, affordable, and accessible transit solutions for their citizens. IPT, which encompasses a range of semi-formal and informal modes such as shared minibuses, autorickshaws, and ride-hailing services emerges as a vital component of urban mobility. Its flexibility, affordability, and accessibility make it a lifeline for millions of residents who rely on it for their daily commutes. Thus, it helps fill the gap between the limited availability of formal public transit and the increasing transportation demands of the population

Indian census data on ‘travel to work’ for the year 2011, reveal that 4.31% of the total work trips are done by IPT, this share is comparatively more than work trips by private cars (3.9%) thus, underscoring the significance of paratransit system in India (Office of the Registrar General and Census Commissioner India., 2011). However, it is important to note that there is no census or official data available on the modal share of IPT in small and medium-sized cities; therefore, this research addresses a critical gap by focusing on IPT usage in a small city context. It has become a vital component of the urban transportation system particularly in small and medium-sized cities, where conventional public transportation is not adequate and suitable to cater to the mobility demands of the travellers. This thesis presents an empirical assessment of the existing role of IPT in Indian cities. The existing literature does not showcase the role and importance of IPT in small cities that are devoid of the formal public transit system. With

Wardha as a case-study city, which is an emerging Tier-3 city in state of Maharashtra, India, this thesis makes a significant contribution to the academic literature as it focuses on the needs and perspectives of IPT users in small-sized cities.

The research carried in this thesis is based on a questionnaire survey data collected from the case-study city. The travel survey results for Wardha city reveal that 39 percent of work trips are made using IPT, emphasizing the importance of this mode of travel in small cities. To maintain the existing patronage, it is crucial to understand user perception of the service of this shared mobility system. Given the infeasibility of high operating costs and lower ridership associated with providing formal public transport in small cities, retaining shared mobility options is crucial to prevent modal shift to private modes such as two-wheelers and four-wheelers. Since IPT can fulfill the mobility demands in small cities, it is imperative to evaluate the service quality of the system.

In case of Indian cities, there is a lack of research that explore the choice among various IPT modes such as cycle-rickshaw, auto, e-rickshaw, and others. This research examines the mode choice behaviour of commuters by considering various paratransit vehicles as alternatives. Further to understand the importance of paratransit service with respect to future use, a test to evaluate loyalty is performed.

It is acknowledged that users' behaviour, satisfaction, and preferences regarding mode choice and service use are all influenced by the perceived quality of the service. Studies that attempt to determine user satisfaction levels (perceived quality of service) provide a valuable tool for transportation authorities and IPT operators in developing new marketing strategies, interventions required for improving quality of service aimed at retaining existing users. The analysis of the relationship between user behaviour, satisfaction, and their choice of IPT mode represents another contribution of this research. An intriguing finding was that although paratransit users in Wardha are not entirely content with the current service quality, they still

opt for this mode of transportation, possibly because they lack access to private vehicles. However, this suggests that people may shift to other private modes, such as cars or motorcycles, if given the opportunity.

The level of service for IPT is strongly associated with user satisfaction and perception, which can significantly impact their overall perception of quality. Having a standard benchmark to understand the expectations of commuters is crucial for enhancing the level of service, which can include improvements in vehicle comfort, service hours, and reliability. These enhancements can result in increased satisfaction and demand for IPT services. However, existing methodologies for LOS evaluation do not specifically address IPT services. This study develops a systematic methodology to describe the LOS that users experience when traveling in IPT, using psychometrics and psychological scaling theory to convert qualitative responses into a quantitative scale. The Level of service index is calculated using the Law of Successive Interval Scaling, for service quality attributes ranging five levels. The LOS thresholds were established for all five paratransit modes. It is worth noting that to develop the LOS index, it's essential not just to understand customers' ratings on various service attributes, but also the importance they assign to these attributes. In this thesis, relative significance of each service quality attribute is taken into consideration. The individual LOS threshold of various attributes are used to generate the index for measuring the overall level of service for specific IPT modes. This research has proposed a LOS index based on user perception, to assess the service quality of different paratransit modes.

The study offers a framework that can help policymakers and planners assess and improve IPT service quality in small cities using user perception and performance indicators. It can also guide infrastructure planning, investment decisions, and be replicated in other cities for broader policy applications. This study can be replicated in other cities, serving as an ideal case to assess and enhance the service quality of the overall transit system in small-sized cities.

**Keywords:** Intermediate Public Transport, Service Quality, Level of Service, Mode choice behaviour, India.

## सारांश

शहरीकरण एक विश्वव्यापी प्रक्रिया है, जिसके कारण गतिशीलता की मांग में वृद्धि हुई है। जैसे-जैसे शहरी क्षेत्रों का विस्तार जारी है, कुशल और उपयोगकर्ता-केंद्रित परिवहन समाधानों की आवश्यकता बढ़ती जा रही है। इंटरमीडिएट पब्लिक ट्रांजिट (आईपीटी) विकासशील देशों के गतिशीलता प्रणाली में एक महत्वपूर्ण भूमिका निभाता है। तेजी से शहरीकरण और बढ़ती आबादी वाले भारतीय शहरों को अक्सर अपने नागरिकों के लिए कुशल, किफायती और सरल पारगमन समाधान प्रदान करने में अनूठी चुनौतियों का सामना करना पड़ता है। आईपीटी, जिसमें साइकिल मिनीबस, ऑटोरिक्शा और राइड-हेलिंग सेवाओं जैसे अर्ध-औपचारिक और अनौपचारिक मोड शामिल हैं, शहरी गतिशीलता का एक महत्वपूर्ण घटक बनकर उभरता है। इस प्रकार, सीमित सरकारी सार्वजनिक पारगमन विकल्पों और आबादी की बढ़ती परिवहन आवश्यकताओं के बीच के फरक को ख़तम करता है। इसका सामर्थ्य और सुलभता इसे उन लाखों निवासियों के लिए अनिवार्य बनाती है जो अपने दैनिक आवागमन के लिए इस पर निर्भर हैं।

वर्ष 2011 में किये गए भारतीय जनगणना के अंतर्गत एक सर्वे 'कार्य के लिए यात्रा' के डेटा से पता चलता है कि कुल कार्य यात्राओं में से 4.31% यात्राएँ आईपीटी द्वारा की जाती हैं, यह हिस्सा तुलनात्मक रूप से निजी कारों (3.9%) द्वारा की गयी कार्य यात्राओं से अधिक है, ये तथ्य, भारत में पैराट्रांजिट सिस्टम के महत्व को रेखांकित करता है। हालाँकि, यह महत्वपूर्ण है कि छोटे और मध्य आकार के शहरों में आईपीटी के मोडल शेयर पर कोई जनगणना या आधिकारिक डेटा उपलब्ध नहीं है; इसलिए, यह शोध छोटे शहरों के संदर्भ में आईपीटी उपयोग पर ध्यान केंद्रित करके एक महत्वपूर्ण खामी को संबोधित करता है। यह विशेष रूप से छोटे और मध्यम आकार के शहरों में शहरी परिवहन प्रणाली का एक महत्वपूर्ण घटक बन गया है, जहाँ पारंपरिक सरकारी सार्वजनिक परिवहन यात्रियों की माँगों को पूरा करने के लिए पर्याप्त और उपयुक्त नहीं है। यह थीसिस भारतीय शहरों में आईपीटी की मौजूदा भूमिका का एक अनुभवजन्य मूल्यांकन प्रस्तुत करती है। मौजूदा साहित्य छोटे शहरों में आईपीटी की भूमिका और महत्व को प्रदर्शित

नहीं करता है जो सरकारी सार्वजनिक परिवहन प्रणाली से रहित हैं। वर्धा को केस-स्टडी शहर के रूप में चुना गया है, जो भारत के महाराष्ट्र राज्य में एक उभरता हुआ टियर-3 शहर है। यह थीसिस अकादमिक साहित्य में एक महत्वपूर्ण योगदान देता है क्योंकि यह छोटे आकार के शहरों में आईपीटी उपयोगकर्ताओं की जरूरतों और दृष्टिकोणों पर ध्यान केंद्रित करता है।

इस थीसिस में किया गया शोध केस-स्टडी शहर से एकत्रित प्रभावली सर्वेक्षण डेटा पर आधारित है। वर्धा शहर के यात्रा सर्वेक्षण के परिणाम बताते हैं कि 39 प्रतिशत कार्य यात्राएं आईपीटी का उपयोग करके की जाती हैं, जो छोटे शहरों में यात्रा के इस तरीके के महत्व पर जोर देता है। मौजूदा संरक्षण को बनाए रखने के लिए, इस साझा गतिशीलता प्रणाली की सेवा के बारे में उपयोगकर्ता की धारणा को समझना महत्वपूर्ण है। छोटे शहरों में औपचारिक सरकारी सार्वजनिक परिवहन प्रदान करने से जुड़ी उच्च परिचालन लागत और कम सवारियों की अव्यवहारिकता को देखते हुए, दोपहिया और चार पहिया वाहनों जैसे निजी साधनों की ओर बदलाव को रोकने के लिए साझा गतिशीलता आईपीटी विकल्पों को बनाए रखना महत्वपूर्ण है। चूंकि आईपीटी छोटे शहरों में गतिशीलता की मांगों को पूरा कर सकता है, इसलिए इस प्रणाली की सेवा गुणवत्ता का मूल्यांकन करना अनिवार्य है।

भारतीय शहरों के मामले में, विभिन्न आईपीटी जैसे साइकिल-रिक्शा, ऑटो, ई-रिक्शा और अन्य विकल्पों के बीच चयन का पता लगाने वाले शोध की कमी है। भविष्य में आईपीटी के इस्तमाल को लेकर वर्धा के लोगो की क्या प्रक्रिया रहेगी यह समझने के लिए, एक परीक्षण किया गया है।

यह सामान्य तौर पर माना जाता है की उपयोगकर्ताओं की संतुष्टि और यात्रा के लिए वाहन विकल्पों के चयन में, सेवा की कथित गुणवत्ता प्रभावित करती हैं। उपयोगकर्ता संतुष्टि के स्तर (सेवा की कथित गुणवत्ता) को निर्धारित करने का प्रयास करने वाले अध्ययन परिवहन अधिकारियों और आईपीटी ऑपरेटरों को नई मार्केटिंग रणनीतियों को विकसित करने, मौजूदा उपयोगकर्ताओं को बनाए रखने के उद्देश्य से, सेवा की गुणवत्ता में सुधार के लिए आवश्यक हस्तक्षेप करने में एक मूल्यवान योगदान प्रदान

करते हैं। उपयोगकर्ता के व्यवहार, संतुष्टि और आईपीटी मोड की उनकी पसंद के बीच संबंधों का विश्लेषण इस शोध का एक और योगदान दर्शाता है। एक दिलचस्प खोज यह थी कि हालांकि वर्धा में आईपीटी उपयोगकर्ता वर्तमान सेवा की गुणवत्ता से पूरी तरह संतुष्ट नहीं हैं, फिर भी वे परिवहन के इस तरीके को चुनते हैं, संभवतः इसलिए क्योंकि उनके पास निजी वाहन नहीं है। हालांकि, इससे पता चलता है कि अगर मौका मिले तो लोग कार या मोटरसाइकिल जैसे अन्य निजी साधनों का इस्तेमाल कर सकते हैं।

आईपीटी सेवा का स्तर, उपयोगकर्ता की संतुष्टि और दृढ़ता से जुड़ा हुआ है, जो गुणवत्ता के बारे में उनकी समग्र धारणा को महत्वपूर्ण रूप से प्रभावित कर सकता है। यात्रियों की अपेक्षाओं को समझने के लिए एक बेंचमार्क होना सेवा के स्तर को बढ़ाने के लिए महत्वपूर्ण है, जिसमें वाहन आराम, सेवा घंटे और विश्वसनीयता में सुधार शामिल हो सकते हैं। इन संवर्द्धनों के परिणामस्वरूप आईपीटी सेवाओं के लिए संतुष्टि और मांग में वृद्धि हो सकती है। हालांकि, सेवा का स्तर का मूल्यांकन के लिए मौजूदा पद्धतियाँ में आईपीटी सेवाओं का वर्णन नहीं हैं। यह अध्ययन गुणात्मक प्रतिक्रियाओं को मात्रात्मक पैमाने में बदलने के लिए साइकोमेट्रिक्स और मनोवैज्ञानिक स्केलिंग सिद्धांत का उपयोग करके, आईपीटी में यात्रा करते समय उपयोगकर्ताओं द्वारा अनुभव किए जाने वाले सेवा का स्तर का वर्णन करने के लिए एक व्यवस्थित पद्धति विकसित करता है। सेवा के स्तर के सूचकांक की गणना पाँच स्तरों की सेवा गुणवत्ता विशेषताओं के लिए क्रमिक अंतराल स्केलिंग के नियम का उपयोग करके की जाती है। सभी पाँच आईपीटी मोड के लिए सेवा के स्तर की सीमाएँ स्थापित की गई हैं। यह ध्यान देने योग्य है कि सेवा का स्तर सूचकांक विकसित करने के लिए, न केवल विभिन्न सेवा विशेषताओं पर ग्राहकों की रेटिंग को समझना आवश्यक है, बल्कि इन विशेषताओं को उनके द्वारा दिए जाने वाले महत्व को भी समझना आवश्यक है। इस थीसिस में, प्रत्येक सेवा गुणवत्ता विशेषता के आपेक्षिक महत्व को ध्यान में रखा गया है। विशिष्ट आईपीटी विकल्पों के लिए सेवा के समग्र स्तर को मापने के लिए सूचकांक उत्पन्न करने के लिए विभिन्न विशेषताओं की व्यक्तिगत सेवा का स्तर सीमा का उपयोग किया जाता है। इस शोध में विभिन्न पैराट्रांजिट मोडों की सेवा

गुणवत्ता का आकलन करने के लिए उपयोगकर्ता धारणा के आधार पर एक सेवा का स्तर सूचकांक प्रस्तावित किया गया है।

यह अध्ययन एक ढांचा प्रस्तुत करता है जो नीति निर्माताओं और योजनाकारों को उपयोगकर्ता धारणा और सेवा स्तर सूचकांक के माध्यम से छोटे शहरों में आईपीटी सेवा गुणवत्ता का आकलन और सुधार करने में मदद कर सकता है। यह बुनियादी ढांचे की योजना और निवेश निर्णयों में मार्गदर्शन कर सकता है, और अन्य शहरों में भी दोहराया जा सकता है।

**कीवर्ड्स:** इंटरमीडिएट पब्लिक ट्रांसपोर्ट (आईपीटी), सेवा गुणवत्ता, सेवा का स्तर, वाहन चयन व्यवहार, भारत।

# TABLE OF CONTENTS

|                                                                          |      |
|--------------------------------------------------------------------------|------|
| CERTIFICATE.....                                                         | i    |
| ACKNOWLEDGEMENTS.....                                                    | ii   |
| ABSTRACT .....                                                           | v    |
| TABLE OF CONTENTS .....                                                  | xiii |
| LIST OF FIGURES.....                                                     | xx   |
| LIST OF TABLES .....                                                     | xxiv |
| LIST OF ABBREVIATIONS .....                                              | xxxi |
| CHAPTER 1 INTRODUCTION .....                                             | 1    |
| 1.1 Background.....                                                      | 1    |
| 1.2 Exploring the concept of IPT .....                                   | 1    |
| 1.3 Significance of IPT.....                                             | 4    |
| 1.4 Research focus and Motivation.....                                   | 7    |
| 1.5 Aim of the study.....                                                | 11   |
| 1.5.1 Goals of the study.....                                            | 11   |
| 1.6 Objectives of the study .....                                        | 11   |
| 1.7 Thesis organization.....                                             | 13   |
| CHAPTER 2 LITERATURE REVIEW .....                                        | 15   |
| 2.1 Introduction.....                                                    | 15   |
| 2.2 Study of user behavior in choosing a particular mode of travel ..... | 15   |

|                                                                |                                                                           |    |
|----------------------------------------------------------------|---------------------------------------------------------------------------|----|
| 2.3                                                            | Review of IPT service quality studies .....                               | 19 |
| 2.4                                                            | Understanding the user perception of service quality for paratransit..... | 22 |
| 2.5                                                            | Investigating the concept and dimensions of quality of service. ....      | 24 |
| 2.6                                                            | Research Gaps.....                                                        | 28 |
| 2.7                                                            | Summary.....                                                              | 29 |
| CHAPTER 3 METHODOLOGY.....                                     |                                                                           | 31 |
| 3.1                                                            | Introduction.....                                                         | 31 |
| 3.2                                                            | Research design.....                                                      | 31 |
| 3.3                                                            | Case study city selection.....                                            | 32 |
| 3.3.1                                                          | Overview of the study area – Wardha city.....                             | 36 |
| 3.4                                                            | Survey design.....                                                        | 38 |
| 3.4.1                                                          | Sample design .....                                                       | 38 |
| 3.4.2                                                          | Survey instrument design .....                                            | 41 |
| 3.5                                                            | Survey process and sample summary.....                                    | 42 |
| 3.5.1                                                          | Phase-wise data collection .....                                          | 42 |
| 3.5.2                                                          | Data description.....                                                     | 43 |
| 3.6                                                            | Statistical methods to accomplish research goals. ....                    | 52 |
| 3.6.1                                                          | Review of transportation models .....                                     | 53 |
| 3.7                                                            | Summary.....                                                              | 57 |
| CHAPTER 4 A COMPREHENSIVE ANALYSIS OF INDIA'S IPT SECTOR ..... |                                                                           | 59 |
| 4.1                                                            | Introduction.....                                                         | 59 |

|                                                                                    |                                                                    |    |
|------------------------------------------------------------------------------------|--------------------------------------------------------------------|----|
| 4.2                                                                                | Research contribution and objectives .....                         | 60 |
| 4.3                                                                                | Research Approach.....                                             | 61 |
| 4.4                                                                                | Describing IPT .....                                               | 62 |
| 4.5                                                                                | Classifying IPT.....                                               | 62 |
| 4.6                                                                                | Role of IPT in India.....                                          | 65 |
| 4.7                                                                                | Understanding the existing scenario of IPT in Indian cities .....  | 67 |
| 4.7.1                                                                              | Introduction of Electric Vehicles.....                             | 69 |
| 4.7.2                                                                              | Studying Census data .....                                         | 70 |
| 4.8                                                                                | Review of government policies and regulations for IPT .....        | 75 |
| 4.8.1                                                                              | International case studies .....                                   | 79 |
| 4.9                                                                                | Advantages and shortcomings of the IPT sector.....                 | 82 |
| 4.10                                                                               | Implications for the managerial practice of IPT in India.....      | 83 |
| 4.11                                                                               | Summary .....                                                      | 85 |
| CHAPTER 5 ANALYSING COMMUTER BEHAVIOUR AND TRAVEL PATTERNS<br>WITH IPT MODES ..... |                                                                    | 87 |
| 5.1                                                                                | Introduction.....                                                  | 87 |
| 5.2                                                                                | Research contribution and objectives.....                          | 88 |
| 5.3                                                                                | Data description .....                                             | 89 |
| 5.4                                                                                | Results and Discussion .....                                       | 94 |
| 5.4.1                                                                              | Study mode choice for work trips for residents of Wardha city..... | 94 |
| 5.4.2                                                                              | Investigate mode choice for IPT trips .....                        | 98 |

|                                                                                                                     |                                                                                  |     |
|---------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|-----|
| 5.4.3                                                                                                               | Investigating the customer's loyalty in choosing a particular paratransit mode.. | 106 |
| 5.5                                                                                                                 | Summary.....                                                                     | 110 |
| CHAPTER 6 ANALYSING USER PERCEPTIONS WITH IPT MODES .....                                                           |                                                                                  | 113 |
| 6.1                                                                                                                 | Introduction.....                                                                | 113 |
| 6.2                                                                                                                 | Research contribution and Objectives .....                                       | 114 |
| 6.3                                                                                                                 | Research approach.....                                                           | 115 |
| 6.3.1                                                                                                               | Data description .....                                                           | 115 |
| 6.3.2                                                                                                               | Proposed hypothesis and model.....                                               | 117 |
| 6.4                                                                                                                 | Factor analysis.....                                                             | 119 |
| 6.5                                                                                                                 | Measurement model results .....                                                  | 122 |
| 6.5.1                                                                                                               | Discussion of the results .....                                                  | 126 |
| 6.6                                                                                                                 | Summary.....                                                                     | 127 |
| CHAPTER 7 DEVELOPING COMPREHENSIVE LOS MEASURES TO EVALUATE THE PERFORMANCE OF IPT IN SMALL-SIZE INDIAN CITIES..... |                                                                                  | 129 |
| 7.1                                                                                                                 | Introduction.....                                                                | 129 |
| 7.2                                                                                                                 | Research contribution and Objectives .....                                       | 130 |
| 7.3                                                                                                                 | Data description .....                                                           | 132 |
| 7.4                                                                                                                 | Determining LOS for Auto-rickshaw .....                                          | 136 |
| 7.4.1                                                                                                               | Determining LOS threshold for service hours of an auto-rickshaw.....             | 136 |
| 7.4.2                                                                                                               | Determining LOS threshold for overcrowding of auto-rickshaw .....                | 140 |
| 7.4.3                                                                                                               | Determining LOS threshold for waiting time of auto-rickshaw .....                | 143 |

|       |                                                                                              |     |
|-------|----------------------------------------------------------------------------------------------|-----|
| 7.4.4 | Determining LOS threshold for delay of auto-rickshaw .....                                   | 145 |
| 7.4.5 | Determining LOS threshold for access distance of auto-rickshaw .....                         | 147 |
| 7.4.6 | Determining overall LOS benchmarks for all five service indicators of auto-rickshaw .....    | 149 |
| 7.5   | Determining LOS for Rental taxi .....                                                        | 152 |
| 7.5.1 | Determining LOS threshold for service hours of rental-taxi .....                             | 152 |
| 7.5.2 | Determining LOS threshold for overcrowding of rental-taxi .....                              | 154 |
| 7.5.3 | Determining LOS threshold for delay of rental taxi .....                                     | 157 |
| 7.5.4 | Determining LOS threshold for waiting time of rental taxi.....                               | 159 |
| 7.5.5 | Determining LOS threshold for access distance of rental taxi .....                           | 161 |
| 7.5.6 | Determining overall LOS benchmarks for all five service indicators of rental taxi .....      | 163 |
| 7.6   | Determining LOS for shared local taxi.....                                                   | 164 |
| 7.6.1 | Determining LOS threshold for service hours of shared local taxi.....                        | 164 |
| 7.6.2 | Determining LOS threshold for overcrowding of shared local taxi.....                         | 166 |
| 7.6.3 | Determining LOS threshold for delay of shared local taxi.....                                | 168 |
| 7.6.4 | Determining LOS threshold for waiting time of shared local taxi.....                         | 170 |
| 7.6.5 | Determining LOS threshold for access distance of shared local taxi.....                      | 172 |
| 7.6.6 | Determining overall LOS benchmarks for all five service indicators of shared local taxi..... | 174 |
| 7.7   | Determining LOS for 6-seater big auto .....                                                  | 175 |
| 7.7.1 | Determining LOS threshold for service hours of 6-seater big auto .....                       | 175 |

|           |                                                                                               |     |
|-----------|-----------------------------------------------------------------------------------------------|-----|
| 7.7.2     | Determining LOS threshold for overcrowding of 6-seater big auto .....                         | 178 |
| 7.7.3     | Determining LOS threshold for delay of 6-seater big auto .....                                | 180 |
| 7.7.4     | Determining LOS threshold for waiting time of 6-seater big auto .....                         | 182 |
| 7.7.5     | Determining LOS threshold for access distance of 6-seater big auto .....                      | 184 |
| 7.7.6     | Determining overall LOS benchmarks for all five service indicators of 6-seater big auto ..... | 186 |
| 7.8       | Determining LOS for cycle-rickshaw .....                                                      | 187 |
| 7.8.1     | Determining LOS threshold for service hours of cycle-rickshaw.....                            | 187 |
| 7.8.2     | Determining LOS threshold for overcrowding of cycle-rickshaw.....                             | 189 |
| 7.8.3     | Determining LOS threshold for waiting time of cycle-rickshaw.....                             | 191 |
| 7.8.4     | Determining LOS threshold for delay of cycle-rickshaw.....                                    | 193 |
| 7.8.5     | Determining LOS threshold for access distance of cycle-rickshaw.....                          | 194 |
| 7.8.6     | Determining overall LOS benchmarks for all five service indicators of cycle-rickshaw .....    | 196 |
| 7.9       | Evaluating of overall LOS of all IPT modes in Wardha.....                                     | 198 |
| 7.10      | Summary.....                                                                                  | 198 |
| CHAPTER 8 | SUMMARY, CONCLUSIONS AND SCOPE FOR FUTURE RESEARCH .                                          |     |
|           | .....                                                                                         | 201 |
| 8.1       | Summary.....                                                                                  | 201 |
| 8.2       | Major findings.....                                                                           | 202 |
| 8.3       | Contributions of research.....                                                                | 203 |
| 8.4       | Discussion and Policy Implications .....                                                      | 204 |

|                                                                      |                                    |     |
|----------------------------------------------------------------------|------------------------------------|-----|
| 8.5                                                                  | Limitations and Future Scope ..... | 207 |
| REFERENCES .....                                                     |                                    | 209 |
| APPENDIX .....                                                       |                                    | 241 |
| APPENDIX A: Questionnaire survey form.....                           |                                    | 241 |
| APPENDIX B: Existing scenario of IPT in Wardha city .....            |                                    | 245 |
| APPENDIX C: Types of IPT vehicles in India.....                      |                                    | 250 |
| APPENDIX D: Correlation matrix of input variables of MNL model. .... |                                    | 253 |
| LIST OF PUBLICATIONS .....                                           |                                    | 255 |
| BRIEF BIO OF AUTHOR .....                                            |                                    | 257 |

## LIST OF FIGURES

|                                                                                                                                                                       |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 2-1 Scientific contribution of countries.....                                                                                                                  | 19  |
| Figure 2-2 Co-occurrence network of keywords .....                                                                                                                    | 20  |
| Figure 2-3 Co-authorship network of countries.....                                                                                                                    | 21  |
| Figure 2-4 IPT vehicles; Sub-domains of IPT service quality studies. ....                                                                                             | 21  |
| Figure 2-5 Graphical representation: Case studies across the globe.....                                                                                               | 22  |
| Figure 3-1 Research Methodology.....                                                                                                                                  | 33  |
| Figure 3-2 Location map of Wardha .....                                                                                                                               | 36  |
| Figure 3-3 Development Plan of Wardha.....                                                                                                                            | 37  |
| Figure 3-4 Survey area: Wardha Municipal Corporation boundary.....                                                                                                    | 37  |
| Figure 3-5 Data required for each objective based on the source of collection .....                                                                                   | 38  |
| Figure 3-6 Mode of travel to work.....                                                                                                                                | 46  |
| Figure 3-7 Comparing vehicle ownership and choice of mode for work travel purpose.....                                                                                | 47  |
| Figure 3-8 Respondents opinion regarding willingness to use IPT modes in future. ....                                                                                 | 49  |
| Figure 3-9 Respondents opinion regarding willingness to recommend use of IPT modes. ....                                                                              | 50  |
| Figure 3-10 Trip purpose and trip distance for different IPT modes. ....                                                                                              | 50  |
| Figure 4-1 Classification of IPT .....                                                                                                                                | 65  |
| Figure 5-1 Frequency of use (%) of IPT vehicles.....                                                                                                                  | 92  |
| Figure 5-2 IPT Vehicles by the trip purpose and travel distance. ....                                                                                                 | 92  |
| Figure 5-3 Trip length of IPT vehicles: (a) Auto-rickshaw; (b) 6-Seater Big Auto; (c) Cycle-rickshaw; (d) E-rickshaw; (e) Minibus; (f) Taxi Car; (g) Shared Taxi..... | 93  |
| Figure 5-4 Percentage of trips by various IPT vehicles .....                                                                                                          | 101 |
| Figure 5-5 SEM model framework for testing loyalty of IPT commuters. ....                                                                                             | 107 |
| Figure 6-1 Overall satisfaction perceived from utilizing five different IPT modes .....                                                                               | 117 |

|                                                                                                                                                    |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 6-2 SEM framework for studying user satisfaction. ....                                                                                      | 119 |
| Figure 7-1 Service hours served by different IPT vehicles .....                                                                                    | 134 |
| Figure 7-2 Access distance to IPT .....                                                                                                            | 134 |
| Figure 7-3 Waiting time for various IPT modes.....                                                                                                 | 135 |
| Figure 7-4 Delay involved while travelling in an IPT vehicle. ....                                                                                 | 135 |
| Figure 7-5 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for service hours of auto-rickshaw.....   | 139 |
| Figure 7-6 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for overcrowding of auto-rickshaw.....    | 142 |
| Figure 7-7 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for waiting time of auto-rickshaw.....    | 144 |
| Figure 7-8 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for delay of auto-rickshaw.....           | 146 |
| Figure 7-9 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for access distance of auto-rickshaw..... | 148 |
| Figure 7-10 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for service hours of rental taxi .....   | 153 |
| Figure 7-11 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for overcrowding of rental taxi .....    | 156 |
| Figure 7-12 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for delay of rental taxi .....           | 158 |
| Figure 7-13 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for waiting time of rental taxi .....    | 160 |
| Figure 7-14 The optimal curve capturing the relationship between $\mu_{jLOS}$ and average service levels, for access distance of rental taxi ..... | 162 |

|                                                                                                                                                         |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 7-15 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for service hours of shared local taxi .....   | 165 |
| Figure 7-16 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for the overcrowding of shared local taxi..... | 167 |
| Figure 7-17 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for delay of shared local taxi .....           | 169 |
| Figure 7-18 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for waiting time of shared local taxi .....    | 171 |
| Figure 7-19 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for access distance of shared local taxi ..... | 173 |
| Figure 7-20 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for service hours of 6-seater big auto .....   | 177 |
| Figure 7-21 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for overcrowding of 6-seater big auto .....    | 179 |
| Figure 7-22 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for delay of 6-seater big auto .....           | 181 |
| Figure 7-23 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for waiting time of 6-seater big auto .....    | 183 |
| Figure 7-24 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for access distance of 6-seater big auto ..... | 185 |
| Figure 7-25 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for service hours of cycle-rickshaw .....      | 188 |
| Figure 7-26 The optimal curve capturing the relationship between $\mu_j$ LOS and average service levels, for overcrowding of cycle-rickshaw .....       | 190 |

|                                                                                                                                                     |     |
|-----------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Figure 7-27 The optimal curve capturing the relationship between $\mu$ jLOS and average service levels, for waiting time of cycle-rickshaw .....    | 192 |
| Figure 7-28 The optimal curve capturing the relationship between $\mu$ jLOS and average service levels, for delay of cycle-rickshaw .....           | 194 |
| Figure 7-29 The optimal curve capturing the relationship between $\mu$ jLOS and average service levels, for access distance of cycle-rickshaw ..... | 196 |

## LIST OF TABLES

|                                                                                                      |     |
|------------------------------------------------------------------------------------------------------|-----|
| Table 1.1 Terminology of IPT vehicle types across different countries.....                           | 4   |
| Table 3.1 State-wise percentage share of IPT trips.....                                              | 35  |
| Table 3.2 District-wise percentage share of IPT trips. ....                                          | 35  |
| Table 3.3 Phase-wise duration of data collection.....                                                | 42  |
| Table 3.4 Descriptive analysis of socio-demographic characteristics of respondents. ....             | 44  |
| Table 3.5 Comparing sample data with Census record, 2011.....                                        | 45  |
| Table 4.1 Definition of IPT.....                                                                     | 63  |
| Table 4.2 Number of public transport buses and number of registered paratransit (year 2013)<br>..... | 68  |
| Table 4.3 Number of registered paratransit vehicles (year 2020).....                                 | 69  |
| Table 4.4 State/UT with maximum percentage share of IPT work trips.....                              | 71  |
| Table 4.5 State/UT with minimal percentage share of IPT work trips.....                              | 71  |
| Table 4.6 Districts with the maximum share of IPT work trips.....                                    | 72  |
| Table 4.7 Districts with a minimum share of IPT work trips .....                                     | 72  |
| Table 4.8 IPT share for the most populous districts.....                                             | 73  |
| Table 4.9 IPT share for the least populous districts .....                                           | 73  |
| Table 4.10 IPT share for Urban districts of India .....                                              | 74  |
| Table 4.11 Pearson correlation analysis for 640 districts .....                                      | 74  |
| Table 4.12 Policy interventions at global level.....                                                 | 80  |
| Table 5.1 Summary of respondent's socio-demographic characteristics .....                            | 90  |
| Table 5.2 Mode choice MNL model results for travel to work purpose. ....                             | 96  |
| Table 5.3 MNL model results for choice of IPT mode.....                                              | 104 |
| Table 5.4 Estimation results of paratransit loyalty.....                                             | 109 |

|                                                                                                                                                      |     |
|------------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 5.5 Summary of indirect effect of socio-demographic variables on choice of IPT modes.<br>.....                                                 | 110 |
| Table 6.1 Descriptive summary of the ratings observed for satisfaction indicators of IPT<br>services .....                                           | 116 |
| Table 6.2 Summary of factor analysis: PCA and CFA .....                                                                                              | 121 |
| Table 6.3 Output results of proposed SEM model – Direct Effects.....                                                                                 | 123 |
| Table 6.4 Output results of proposed SEM model – Indirect Effects. ....                                                                              | 124 |
| Table 7.1 Mean and standard deviation of the ratings observed for satisfaction indices.....                                                          | 133 |
| Table 7.2 Summary of responses recorded w.r.t. service hours for auto-rickshaw. ....                                                                 | 137 |
| Table 7.3 Normal deviates ( $y_{jk}$ ) corresponding to the cumulative proportions ( $p_{jk}$ ) of the<br>responses.....                             | 138 |
| Table 7.4 Mean LOS rating ( $\mu_{jLOS}$ ) values for each service range (j).....                                                                    | 138 |
| Table 7.5 Service levels for the upper limit of each kth category. ....                                                                              | 140 |
| Table 7.6 LOS thresholds for service hours of auto-rickshaw .....                                                                                    | 140 |
| Table 7.7 Summary of responses recorded w.r.t. overcrowding for auto-rickshaw. ....                                                                  | 141 |
| Table 7.8 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for<br>each service range (j) .....  | 141 |
| Table 7.9 Service levels for the upper limit of each k <sup>th</sup> category. ....                                                                  | 142 |
| Table 7.10 LOS thresholds for overcrowding of auto-rickshaw .....                                                                                    | 142 |
| Table 7.11 Summary of responses recorded w.r.t. waiting time for auto-rickshaw. ....                                                                 | 143 |
| Table 7.12 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for<br>each service range (j) ..... | 143 |
| Table 7.13 Service levels for the upper limit of each k <sup>th</sup> category. ....                                                                 | 145 |
| Table 7.14 LOS thresholds for waiting time of auto-rickshaw. ....                                                                                    | 145 |
| Table 7.15 Summary of responses recorded w.r.t. delay for auto-rickshaw. ....                                                                        | 145 |

|                                                                                                                                                   |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.16 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 146 |
| Table 7.17 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 147 |
| Table 7.18 LOS thresholds for delay of auto-rickshaw .....                                                                                        | 147 |
| Table 7.19 Summary of responses recorded w.r.t. access distance for auto-rickshaw. ....                                                           | 147 |
| Table 7.20 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 148 |
| Table 7.21 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 149 |
| Table 7.22 LOS thresholds for access distance of auto-rickshaw .....                                                                              | 149 |
| Table 7.23 LOS threshold values for service quality of auto-rickshaw .....                                                                        | 150 |
| Table 7.24 LOS scale values for IPT performance in Wardha city. ....                                                                              | 151 |
| Table 7.25 Summary of responses recorded w.r.t. service hours for rental taxi. ....                                                               | 152 |
| Table 7.26 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 153 |
| Table 7.27 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 154 |
| Table 7.28 LOS thresholds for service hours of rental taxi.....                                                                                   | 154 |
| Table 7.29 Summary of responses recorded w.r.t. overcrowding for rental taxi. ....                                                                | 155 |
| Table 7.30 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 155 |
| Table 7.31 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 156 |
| Table 7.32 LOS thresholds for overcrowding of rental taxi.....                                                                                    | 156 |
| Table 7.33 Summary of responses recorded w.r.t. delay of rental taxi.....                                                                         | 157 |
| Table 7.34 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 157 |
| Table 7.35 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 158 |

|                                                                                                                                                   |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.36 LOS thresholds for delay of rental taxi.....                                                                                           | 158 |
| Table 7.37 Summary of responses recorded w.r.t. waiting time for rental taxi.....                                                                 | 159 |
| Table 7.38 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 159 |
| Table 7.39 Service levels for the upper limit of each kth category. ....                                                                          | 160 |
| Table 7.40 LOS thresholds for waiting time of rental taxi.....                                                                                    | 160 |
| Table 7.41 Summary of responses recorded w.r.t. access distance of rental taxi.....                                                               | 161 |
| Table 7.42 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 161 |
| Table 7.43 Service levels for the upper limit of each kth category .....                                                                          | 162 |
| Table 7.44 LOS thresholds for access distance of rental taxi.....                                                                                 | 162 |
| Table 7.45 LOS threshold values for service quality of rental taxis.....                                                                          | 163 |
| Table 7.46 Summary of responses recorded w.r.t. service hours of shared local taxi. ....                                                          | 164 |
| Table 7.47 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 165 |
| Table 7.48 Service levels for the upper limit of each k <sup>th</sup> category. ....                                                              | 166 |
| Table 7.49 LOS thresholds for service hours of shared local taxi .....                                                                            | 166 |
| Table 7.50 Summary of responses recorded w.r.t. the overcrowding of shared local taxi. ..                                                         | 166 |
| Table 7.51 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 167 |
| Table 7.52 Service levels for the upper limit of each kth category. ....                                                                          | 168 |
| Table 7.53 LOS thresholds for the overcrowding of shared local taxi .....                                                                         | 168 |
| Table 7.54 Summary of responses recorded w.r.t. delay of shared local taxi. ....                                                                  | 168 |
| Table 7.55 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 169 |

|                                                                                                                                                   |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.56 Service levels for the upper limit of each $k^{\text{th}}$ category. ....                                                              | 170 |
| Table 7.57 LOS thresholds for delay of shared local taxi .....                                                                                    | 170 |
| Table 7.58 Summary of responses recorded w.r.t. waiting time of shared local taxi. ....                                                           | 170 |
| Table 7.59 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 171 |
| Table 7.60 Service levels for the upper limit of each $k^{\text{th}}$ category. ....                                                              | 172 |
| Table 7.61 LOS thresholds for waiting time of shared local taxi .....                                                                             | 172 |
| Table 7.62 Summary of responses recorded w.r.t. access distance of shared local taxi. ....                                                        | 172 |
| Table 7.63 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 173 |
| Table 7.64 Service levels for the upper limit of each $k^{\text{th}}$ category. ....                                                              | 174 |
| Table 7.65 LOS thresholds for access distance of shared local taxi .....                                                                          | 174 |
| Table 7.66 LOS threshold values for service quality of shared local taxis .....                                                                   | 175 |
| Table 7.67 Summary of responses recorded w.r.t. service hours of 6-seater big auto.....                                                           | 176 |
| Table 7.68 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 176 |
| Table 7.69 Service levels for the upper limit of each $k^{\text{th}}$ category. ....                                                              | 177 |
| Table 7.70 LOS thresholds for service hours of 6-seater big auto .....                                                                            | 177 |
| Table 7.71 Summary of responses recorded w.r.t. overcrowding for 6-seater big auto. ....                                                          | 178 |
| Table 7.72 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 178 |
| Table 7.73 Service levels for the upper limit of each $k^{\text{th}}$ category. ....                                                              | 179 |
| Table 7.74 LOS thresholds for overcrowding of 6-seater big auto .....                                                                             | 179 |
| Table 7.75 Summary of responses recorded w.r.t. delay of 6-seater big auto.....                                                                   | 180 |

|                                                                                                                                                   |     |
|---------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.76 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 180 |
| Table 7.77 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 181 |
| Table 7.78 LOS thresholds for delay of 6-seater big auto .....                                                                                    | 181 |
| Table 7.79 Summary of responses recorded w.r.t. waiting time for 6-seater big auto. ....                                                          | 182 |
| Table 7.80 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 182 |
| Table 7.81 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 183 |
| Table 7.82 LOS thresholds for waiting time of 6-seater big auto.....                                                                              | 183 |
| Table 7.83 Summary of responses recorded w.r.t. access distance of 6-seater big auto.....                                                         | 184 |
| Table 7.84 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 184 |
| Table 7.85 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 185 |
| Table 7.86 LOS thresholds for access distance of 6-seater big auto .....                                                                          | 185 |
| Table 7.87 LOS threshold values for service quality of 6-seater big auto.....                                                                     | 186 |
| Table 7.88 Summary of responses recorded w.r.t. service hours for cycle-rickshaw.....                                                             | 187 |
| Table 7.89 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 188 |
| Table 7.90 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 189 |
| Table 7.91 LOS thresholds for service hours of cycle-rickshaw.....                                                                                | 189 |
| Table 7.92 Summary of responses recorded w.r.t. overcrowding of cycle-rickshaw.....                                                               | 189 |
| Table 7.93 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 189 |
| Table 7.94 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 190 |
| Table 7.95 LOS thresholds for overcrowding of cycle-rickshaw.....                                                                                 | 190 |

|                                                                                                                                                    |     |
|----------------------------------------------------------------------------------------------------------------------------------------------------|-----|
| Table 7.96 Summary of responses recorded w.r.t. waiting time of cycle-rickshaw.....                                                                | 191 |
| Table 7.97 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) .....  | 191 |
| Table 7.98 Service levels for the upper limit of each $k^{th}$ category. ....                                                                      | 192 |
| Table 7.99 LOS thresholds for waiting time of cycle-rickshaw .....                                                                                 | 192 |
| Table 7.100 Summary of responses recorded w.r.t. delay of cycle-rickshaw. ....                                                                     | 193 |
| Table 7.101 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 193 |
| Table 7.102 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 194 |
| Table 7.103 LOS thresholds for delay of cycle-rickshaw .....                                                                                       | 194 |
| Table 7.104 Summary of responses recorded w.r.t. access distance of cycle-rickshaw. ....                                                           | 195 |
| Table 7.105 Normal deviates ( $y_{jk}$ ), normalized average ( $\mu_{kUB}$ ) and mean LOS rating ( $\mu_{jLOS}$ ) for each service range (j) ..... | 195 |
| Table 7.106 Service levels for the upper limit of each $k^{th}$ category. ....                                                                     | 196 |
| Table 7.107 LOS thresholds for access distance of cycle-rickshaw .....                                                                             | 196 |
| Table 7.108 LOS threshold values for service quality of cycle-rickshaw .....                                                                       | 197 |
| Table 7.109 Calculated LOS ratings for all IPT modes of Wardha city .....                                                                          | 198 |
| Table B0.1 Existing Auto-rickshaw scenario in Wardha city .....                                                                                    | 245 |
| Table B0.2 Existing Rental taxi scenario in Wardha city .....                                                                                      | 246 |
| Table B0.3 Existing Shared local taxi scenario in Wardha city .....                                                                                | 247 |
| Table B0.4 Existing 6-Seater big auto scenario in Wardha city .....                                                                                | 248 |
| Table B0.5 Existing Cycle-rickshaw scenario in Wardha city .....                                                                                   | 249 |

## **LIST OF ABBREVIATIONS**

AGFI- Adjusted Goodness of Fit Index

AHP- Analytic Hierarchy Process

ASHA- Accredited Social Health Activist

BRT- Bus Rapid Transit

CDIA- Cities Development Initiative for Asia

CFA- Confirmatory Factor Analysis

CFI- Comparative Fit Index

CMP- Comprehensive Mobility Plan

CNG- Compressed Natural Gas

DRTLA- Dar es Salaam Regional Transport Licensing Authority

EFA- Exploratory factor analysis

EV – Electric Vehicles

FA- Factor Analysis

GEV- Generalized Extreme Value

GFI - Goodness of Fit Index

GPS- Global Positioning System

HH- Household

IIA- Independence of Irrelevant Alternatives

IPT- Intermediate Public Transport

ITS- Intelligent Transport Systems

KMO- Kaiser-Meyer-Olkin

LBP- Land Bank of the Philippines

LOS- Level-of-Service

LPG- Liquefied Petroleum Gas

MDCEV- Multiple Discrete-Continuous Extreme Value

MIMIC- Multiple-Indicator, Multiple-Cause Model

MNL- Multinomial Logistic Regression

MSA- Measure of Sampling Adequacy

MOHUA- Ministry of Housing and Urban Affairs

MoUD- Ministry of Urban Development

NCT- National Capital Territory

NMT- Non-motorised Transport

PCA - Principal Component Analysis

RMSEA- Root Mean Square Error of Approximation

RTO- Regional Transport Office

SANTACO - South African National Taxi Council

SEM- Structural Equation Modeling

SERVQUAL- SERVICE QUALity

SUV- Sports Utility Vehicle

SLTDA- Sri Lanka Tourism Development Authority

TCQSM- Transit Capacity and Quality of Service Manual

TLI- Tucker-Lewis index

TRP- Taxi Recapitalization Program

(Page intentionally left blank)