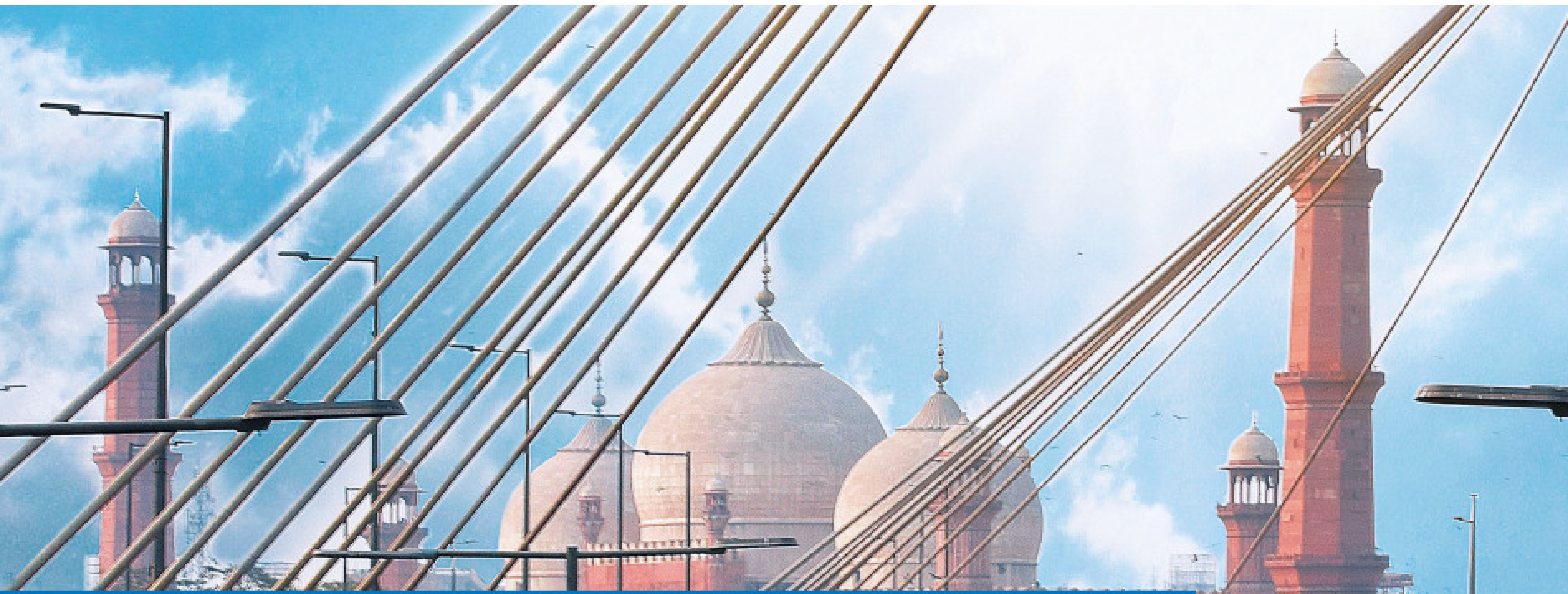

Urban Transition as a Result of Transport Investment: The Case Bus Rapid Transit Lahore Pakistan

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Doctoral dissertation submitted to obtain the academic degrees of

Doctor of Urbanism and Spatial Planning (UGent) and Doctor of Transportation Sciences (UHasselt)

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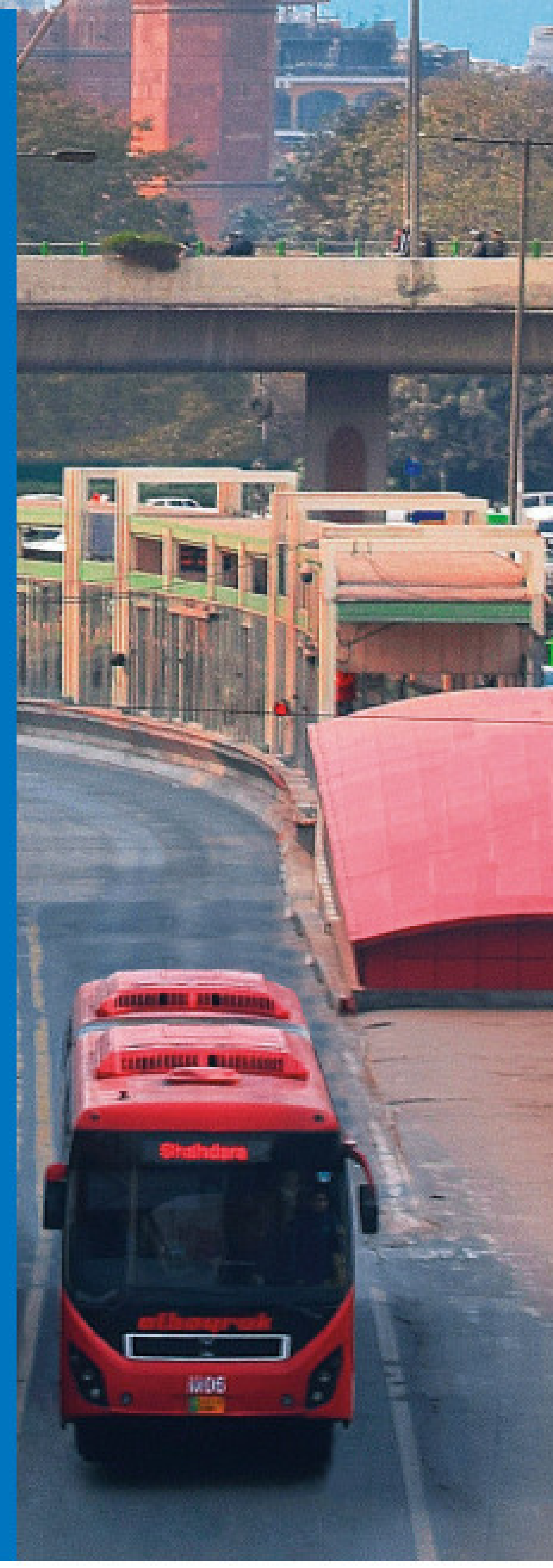
June 2021



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ACKNOWLEDGMENT

All praise be to Almighty Allah (Subhaana hoo Wa Ta' ala) who blessed me with patience, consistency, and resources to acquire the necessary skills for accomplishing this colossal task. I must thank all my promoters (Prof. Dr. Luuk Boelens, Prof. Dr. Davy JANSSENS, and Prof. Dr. Robert Van der Bijl), who extended their invaluable and untiring intellectual capabilities right from scratch to finish this work. Their immense knowledge and quality consciousness kept me on track. The research is the result of approximately 3.5 years-long effort during which I faced many challenges, but encouragement and enthusiasm that I received from my promoters helped me a lot throughout this trajectory. I would also like to thank all the doctoral committee members for their valuable and constructive remarks.

I would also like to thank my respected father Mr. Basheer Ahmad Tahir, my mother and all my siblings, who were always there for me. Especial thanks to my better half and daughter, for supporting me during my Ph.D. as I barely had time to spend with them. Their immense love and support helped me a lot in completing my work.

I would like to share my gratitude to my AMRP colleagues for their help and emotional support throughout the course of my Ph.D. I consider myself lucky to have such supportive Ph.D. fellows. I hereby extend my exclusive appreciation to Mr. Peter Davids, Mr. Syyed Adnan Raheel Shah, and Ms. Areesha Gul for their valuable insight and unconditional support. Moreover, I would like to acknowledge support from my friends, Mr. Mashhood Arif, Mr. Ahamd Adeel, and Mr. Kahlid Javed for making this journey easy for me and helping me in every situation.

Last but not the least, I would like to thank my funding institute (e.g. Higher Education Commission of Pakistan), for providing me with the opportunity to complete my studies at one of the best institutes in the world. The time I spend at Ghent University and Universiteit Hasselt was a virtuous experience for me during which I have learned advanced data collection and modeling techniques. Both institutes had played a great share in my personal development that would definitely help me in the forthcoming.

Muhammad Aamir Basheer
June 2021, Gent

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ACRONYMS

ANT	Actor Network Theory
ARA	Actor Relational Approach
ANOVA	Analysis of Variance
BRT	Bus Rapid Transit
GIS	Geographic Information System
GWR	Geographically Weighted Regression
ITDP	Institute for Transportation and Development Policy
ITS	Intelligent Transportation System
IMPL	Integrated Master Plan for Lahore
LRT	Light Rail Transit
LDA	Lahore Development Authority
LTC	Lahore Transport Company
LUTMP	Lahore Urban Transport Master Plan
PMA	Punjab Masstransit Authority
PPHPP	Passenger per hour per direction
ROW	Right of Way
TOD	Transit Oriented Development
TEPA	Traffic Engineering and Transport Planning Agency
TPU	Transport Planning Unit

SAMENVATTING

De snelle bevolkingsgroei en de verstedelijking hebben de behoefte aan verschillende wijzen van vervoer over de hele wereld doen toenemen. Bovendien heeft de druk in dichtbevolkte stedelijke gebieden mensen gedwongen aan de rand van de stad te gaan wonen. Door deze bevolkingsspreiding langs de stadsranden is de behoefte aan mobiliteit vergroot, waardoor de meeste mensen gebruik maken van eigen auto's om aan hun mobiliteitsvragen tegemoet te komen. Deze toename van het autoverkeer leidt tot tal van problemen, waaronder de aantasting van het milieu, een toename van het energieverbruik, verkeersopstoppingen, meer verkeersongevallen, vertragingen bij het reizen, geluidsoverlast en luchtverontreiniging. Daarom doen regeringen er alles aan om autogebruikers over te laten schakelen op duurzamere en groenere vervoerswijzen. Bus Rapid Transit (BRT) heeft over de hele wereld aan populariteit gewonnen, vooral in ontwikkelingslanden, vanwege de kosteneffectiviteit in tegenstelling tot dure spoor- en lightrailsystemen. Aangezien de ontwikkelingslanden over onvoldoende kapitaal beschikken, is BRT, gezien deze kosteneffectiviteit, steeds aantrekkelijker geworden voor overheidsinvesteringen. De meeste BRT-systemen zijn echter nog betrekkelijk nieuw, zodat er nog onvoldoende empirisch bewijs is voor de effecten ervan op stedelijke ontwikkeling, reisgedrag en economie. Er is weinig onderzoek gedaan naar de voordelen van de ontwikkeling van BRT, vooral op de volgende drie belangrijke aspecten. Ten eerste is er onvoldoende onderzoek gedaan naar BRT vanuit het perspectief van de eindgebruiker. Dit is problematisch omdat juist die sociale baten van het BRT als rechtvaardiging voor overheidsinvesteringen dienen. Ten tweede worden investeringen in het openbaar vervoer door planologen in de betreffende landen over het algemeen gezien als louter een op mobiliteit gerichte investeringsstrategie, terwijl de effecten van BRT op de vorming van de stad meestal worden genegeerd. Ten derde vertalen de transportinvesteringen zich in hogere grondwaarden. Daarom is het van essentieel belang om het effect van investeringen in openbaar vervoer op grondprijzen en onroerend goed te kwantificeren. Bovendien zijn het ontwikkelen van duurzame steden, duurzaam vervoer en duurzame economische groei drie belangrijke pijlers van de Duurzame Ontwikkelingsdoelstellingen (in het Engels: Sustainable Development Goals - SDGs) die door de Verenigde Naties zijn gedefinieerd. Om onze kennis te vergroten, onderzoekt deze dissertatie die in- en externe voordelen van BRT en probeert dit onderzoek het reisgedrag, de stedelijke ontwikkeling en de economische effecten te kwantificeren die zijn ontstaan na de implementatie van BRT. Deze studie richt zich op BRT in Lahore, Pakistan. Niettemin zou dit onderzoek mogelijk ook als representatief kunnen dienen voor meer ontwikkelingslanden en in het bijzonder voor landen in de regio Zuid-Azië.

Omdat de relatie tussen BRT en landgebruik complex is, maakt dit onderzoek gebruik van een meer gefocuste benadering van dergelijke complexe ruimtelijke systemen, namelijk de actor-relationele benadering om de onderlinge relatie van de verschillende onderdelen van BRT (b.v. vervoer, stedelijke ontwikkeling en economie) in de context van Lahore, Pakistan, vast te stellen. In het verlengde daarvan past deze dissertatie verschillende kwantitatieve en kwalitatieve methoden toe om de effecten van BRT te onderscheiden. Ten eerste worden een binaire logistische regressie- en variantieanalyse (ANOVA) gebruikt om het gedrag van reizigers rondom de vervoerskeuze in pre- en post BRT scenario's te bepalen. Transformaties in landgebruik en verandering in stedelijke dichtheid worden vastgesteld met behulp van kaartanalyses. Voort worden variaties in vastgoedwaarden geschat met behulp van een hedonische prijsanalyse en geografisch gewogen regressie-analyse (GWR). Tenslotte hebben interviews met verschillende belanghebbenden geholpen om de factoren te bepalen die deze transformaties teweegbrengen, als ook de veranderingen in de moelijke rol en in de verantwoordelijkheden van dominante stakeholders en de overheid in deze.

De analyse van het reisgedrag toont aan dat BRT in Lahore substantiële effecten heeft op het gedrag van reizigers. Naast een 'modal shift', heeft BRT ook de keuze voor milieuvriendelijkere vervoerswijzen, zoals het langzaam verkeer, verbeterd. Het blijkt dat de kenmerken van de reizigers, zoals leeftijd, geslacht, beroep, opleiding, inkomen, reisdoel, autobezit een significante invloed hebben op de 'modal shift' naar BRT. Uit de analyse van de gerelateerde kenmerken van BRT (zoals tijd, kosten, veiligheid, betrouwbaarheid, comfort, integratie) blijkt dat reistijd, reiskosten en veiligheid de belangrijkste factoren zijn die de keuze voor BRT beïnvloeden. Een analyse van de prestaties toont een substantieel verschil voor de gemiddelde verandering in reistijd tussen BRT en andere vervoerswijzen aan. BRT-gebruikers hebben minder reistijd in vergelijking met gebruikers van een auto, motorfiets, riksja, of andere vervoerswijzen. Ook werd een verschil in gemiddelde verandering in reiskosten waargenomen tussen BRT- en autogebruikers. BRT geniet de voorkeur als mobiliteitsalternatief in Lahore omdat het goedkoper, sneller en veiliger is in vergelijking met andere vervoerswijzen. Bovendien heeft BRT in Lahore het reispatroon van mensen aanzienlijk beïnvloed.

Het empirisch onderzoek naar de stedelijke ontwikkelingspatronen in Lahore, toonden dat BRT in Lahore de potentie heeft om transformatie van landgebruik te stimuleren. Echter, de mate van transformatie is afhankelijk van de context. Alle beoordeelde BRT-stations hebben geleid tot een toename aan commerciële activiteiten als gevolg van bestemmingswijziging. De resultaten geven aan dat alle gebieden een verandering in landgebruik hebben doorgemaakt; maar de mate van transitie varieert over de gehele corridor. Verandering in bevolking en bebouwingsdichtheid is ook zichtbaar in het studiegebied. Een dergelijke toename is waargenomen bij alle stations, maar verschilt per station. Gemiddeld is de bevolkingsdichtheid toegenomen van 268 tot 299 personen per acre (d.w.z. 108 tot 121 personen per hectare). Bovendien en in vergelijking met de algemene ontwikkelingspatronen in Lahore zijn de gebieden rond BRT steeds aantrekkelijker geworden voor woningen en commerciële activiteiten. De waargenomen veranderingen in landgebruik en nieuwe activiteiten geven dus aan dat BRT in Lahore succesvol is in het aanjagen van veranderingen in landgebruik in de directe omgeving, en meer dan elders in Lahore. Binnen een algemene duurzame beleidsfilosofie kunnen deze eigenschappen efficiënt worden benut bij het creëren van compactere stadswijken.

De economische effecten van BRT, die in dit proefschrift worden onderzocht, hebben vooral betrekking op de effecten op de waarde van onroerend goed, inkomende investeringen en uitbreiding van de arbeidsmarkt. De hedonische prijsanalyse en het GWR-model zijn ontwikkeld om de relatie te onderzoeken tussen vastgoedwaarden en verschillende onafhankelijke variabelen (bijv. vastgoedkenmerken, buurtkenmerken en bereikbaarheid). De hedonische prijsanalyse, als globaal model (HPM), geeft de gemiddelde impact van onafhankelijke variabelen op de vastgoedwaarde, terwijl GWR, als lokaal model, de mogelijkheid biedt om de lokale variaties in vastgoedwaarde te onderzoeken en in kaart te brengen. De resultaten van HPM geven aan dat de fysieke kenmerken van het onroerend goed, zoals de ouderdom van het gebouw en het aantal slaapkamers, significant samenhangen met een waardestijging van het onroerend goed. De breedte van de aanliggende weg wordt ook in verband gebracht met een hogere waarde; terwijl van de bereikbaarheidskenmerken alleen de nabijheid van het BRT-station een significante invloed heeft op de hogere waarde van het onroerend goed. De lokale parameters in kaart gebracht laten een belangrijk verband zien tussen de waarde van onroerend goed en de nabijheid van het BRT-station over de gehele lengte van de BRT corridor. Echter, eigendommen gelegen in het noorden binnen 500 meter van de haltes Shahdara, Timber Market, en Qartaba Chowk station laten een hogere toegenomen waarde zien in vergelijking met eigendommen gelegen rond andere BRT-stations. Waarschijnlijk laat ook de invloed van het centrum van Lahore zich hier gelden. Maar voor de gehele corridor geldt in het algemeen dat een afname van de afstand tot het BRT-station gepaard gaat met een toename van de waarde van het onroerend goed. De waarde varieert echter per station.

Uit de gegevens van BRT-Lahore over inkomende investeringen blijkt ook dat langs de corridor een toename van de economische activiteiten wordt waargenomen. Bijna 22.000 miljoen roepies ($ 140 miljoen Amerikaanse dollar) aan inkomende investeringen is geconstateerd, na de implementatie van de BRT. Dit heeft uiteindelijk ook geresulteerd in ongeveer 800 nieuwe werknemers. Dit geeft aan dat de BRT in Lahore een aanzienlijke invloed heeft gehad op de stedelijke ontwikkeling, het reisgedrag en de economie in de omliggende gebieden. Naast het bieden van mobiliteitsvoordelen, is BRT tot nu succesvol in het genereren van landontwikkeling en economische activiteiten.

De analyse van de onderlinge relatie tussen de verschillende effecten van BRT toont echter aan dat de relatie tussen stedelijke ontwikkeling, vervoer en economische ontwikkeling continu is, omdat de effecten elkaar over en weer beïnvloeden. De ontwikkeling van een vervoerssysteem beïnvloedt verschillende aspecten van stedelijke en economische ontwikkeling. Op dezelfde manier beïnvloeden stedelijke ontwikkeling en economische factoren ook de reispatronen en dus het vervoer. In de toekomst, wanneer er meer hoogbouw langs de BRT komt, zal dit mogelijk ook nieuwe eisen aan het vervoer stellen en leiden tot een opwaardering van de BRT-diensten. Deze onderlinge relatie tussen stadsontwikkeling, vervoer en economie (vice versa) kan worden verklaard aan de hand van de actor-relationele benadering (ARA). Volgens deze benadering beïnvloedt de onderlinge relatie tussen verschillende menselijke en niet-menselijke actoren in een specifieke dynamische omgeving de bewuste actoren én de dynamische omgevingen, wat mogelijk leidt tot verdere co-evolutie. Zo zijn deze actoren en omgevingen samen in een continue staat van ‘innovatieve of destructieve wording’. Dat vraagt om een gericht beleid van betrokken politici en planologen om die ‘wording’ ten goede te keren.

Niettemin blijkt uit de analyse van de rol van de stakeholders en hun verantwoordelijkheden dat er na de BRT-implementatie niet veel is veranderd. Om de exploitatie van het BRT systeem in en rond Lahore te regelen, is weliswaar een nieuwe organisatie opgericht, de ‘Punjab Mass-transit Authority’ (PMA). Maar de oprichting van PMA heeft de rol en verantwoordelijkheden van enkel vervoersgerelateerde organisaties veranderd, waaronder de ‘Lahore Transport Company’ (LTC) en het ‘Traffic Engineering and Transport Planning Agency’ (TEPA); en niet die van de ruimtelijke en economische departementen. Er zijn echter geen speciale beleidsmaatregelen genomen om een bij de BRT aansluitende, gerichte ontwikkeling langs de BRT-corridor aan te moedigen. Daarmee blijft de kwestie van de integratie van ruimtelijke ordening en vervoersontwikkeling in de context van BRT bestaan. Hoewel in 2020 nieuwe bouw- en bestemmingsverordeningen zijn goedgekeurd, blijven deze gericht op hoogbouw in het algemeen. Voorts wordt het ook niet gelijktijdig gericht op een daarbij passende opwaardering van de infrastructuurdiensten. Hier is meer focus nodig! Gezien de huidige omstandigheden en financiële beperkingen is het nodig zich te concentreren op en gebruik te maken van specifieke gebieden rond bepaalde corridors (bijvoorbeeld die van de BRT en de ‘Orange Line’ in het Lahore Urban Transport Master Plan) als plek voor hoogbouw en op hoge dichtheid gebaseerde ontwikkeling.

In dit kader zijn tenslotte een aantal aanbevelingen geformulerd om TOD in Lahore aan te moedigen. Verschillende departementen en instanties houden zich bezig met vervoer en ruimtelijke ontwikkeling met overlappende bevoegdheden. Er bestaat een slechte coördinatie tussen deze actoren (vooral tussen die op het gebied van vervoer en landgebruik), hetgeen vaak leidt tot negatieve spill-overs en inefficiënties. In de eerste plaats beveelt dit onderzoek aan om de rol van de ontwikkelings- en vervoersautoriteit in de context van TOD te herzien. In de huidige versnipperde structuur, waarin de verantwoordelijkheden over verschillende actoren zijn verdeeld, zou één platform of kader een leidende rol moeten spelen bij de integratie van investeringen in ruimtelijke ordening en vervoer. In Lahore staan de stadsontwikkelingsactiviteiten hoofdzakelijk onder toezicht van hetzij de Lahore Development Authority (LDA), hetzij de gemeentelijke overheid. Volgens de Lahore Transport Company (LTC), Punjab Masstransit Authority (PMA), Traffic Engineering and Transport Planning Agency (TEPA) zou de LDA de leidende rol kunnen spelen bij de planning en uitvoering van het TOD-plan. Sterke politieke steun voor een dergelijke insitutionele aanpassing zou kunnen helpen de uitvoering van dit TOD-plan te verbeteren. Een dergelijke geïntegreerd politiek zou kunnen werken me behulp van mechanismen als een aangeschepte controle, samen met gerichte (financiële of institutionele) stimulansen en moet worden aangevuld met een herontwikkelingsplan, vooral gericht op verouderde gebieden.

Voorts beveelt dot onderzoek aan om wijzigingen in de bestemmingsplannen uit te voeren met het oog op een geïntegreerde stedelijke ontwikkeling. Bouw- en bestemmingsvoorschriften moeten worden gewijzigd om hoogbouw op gerichte plekken (ipv. algemeen) aan te moedigen. Hogere dichtheid kan plaats bieden aan nieuwe woningen, wat zou kunnen helpen om de ongebreidelde stadsuitbreiding in Lahore tegen te gaan. Mobiliteitsknooppunten (rond specifieke BRT-stations) kunnen worden aangewezen als plaatsen voor deze hoogbouw. De dichtheid kan worden verminderd op een verdere loop- of fietsafstand van de BRT stations. Een hogere dichtheid kan worden bevorderd door belastingvrijstellingsregelingen in te voeren, en de herverdeling van land in centrale gebieden te ondersteunen. Daarmee kunnen mogelijk ook nieuwe openingen gecreëerd worden voor publiek-private samenwerkingsverbanden. In het verlengde daarvan is he gewenst dat de lokale ontwikkelingsautoriteiten niet alleen de dichtheid verhogen, maar ook oog hebben voor de bijpassende opwaardering van de ondersteunende infrastructuur. Om het gebruik van de BRT in Lahore te bevorderen, wordt aanbevolen te zorgen voor een goede toegankelijkheid van de BRT-stations, en bovendien te zorgen voor toegankelijke straten en trottoirs in de directe omgeving. De integratie van BRT met andere vervoerswijzen is een ander belangrijk aspect, vooral als het gaat om niet-gemotoriseerde vervoerswijzen zoals lopen en fietsen.

Uit dit onderzoek blijkt namelijk dat binnen de onderzochte corridor in Lahore lopen als vervoerswijze is toegenomen na de ontwikkeling van BRT. Een goed netwerk van trottoirs en een aantrekkelijk straatbeeld zouden bijdragen om de doelstelling van een begaanbare stad te behalen; daarnaast zou het een multimodale shift kunnen bevorderen. In dit verband wordt aanbevolgen speciale aandacht te besteden aan het ontwerp van meervoudige stedelijke ruimten rond de TOD. Beleidsmaatregelen, zoals beperkingen op het gebruik van particuliere voertuigen of congestieheffingen in het centrale deel van de stad, kunnen een ‘modal shift’ naar BRT teweegbrengen. Hoewel dit geen gemakkelijke taak is, kan het aanmoedigen van publieke participatie helpen om het doel van duurzamer vervoer te bereiken. Ten slotte is het wegnemen van financiële cross-overs een ander element van groot belang bij de uitvoering van TOD-plannen. Ten eerste kunnen publiek-private samenwerkingen bij de aanleg van grond helpen om extra middelen te genereren. Maar ten tweede kan het beleid inzake de vastlegging van grondwaarde in de toekomst ook voor dit doel worden gebruikt; ipv die winsten volledig te laten weglekken in uitsluitend de zakken van de private grondeigenaren.

De bevindingen van deze studie kunnen in overweging worden genomen alvorens andere ov-systemen in Lahore te implementeren, zoals deze in het Lahore Urban Transport Master Plan zijn opgenomen. Verschillende barrières moeten worden aangepakt, en kansen opgepakt om met toekomstige BRT investeringen met succes de stedelijke omgeving in ontwikkelingslanden vorm te geven. Integratie tussen investeringen in vervoer en ruimtelijke ordening kan een beslissende rol spelen bij het realiseren van compacte en duurzame wijken. Alhoewel dit onderzoek situationeel is, kunnen daarmee de algemende aanbevelingen hieruit bewijzen ook een nuttig instrument te zijn voor de planning van BRT-systemen in andere Zuidoost Aziatische steden.

SUMMARY

The rapid population growth and urbanization have escalated the need for diverse modes of transport around the world. Moreover, the pressure in densely populated urban areas has compelled people to live on fringes of the city. As a consequence, this spread of population along the urban peripheries has amplified the need for mobility, making most people use private cars to satisfy their mobility needs. Numerous problems have emerged with this upsurge of automobiles including environmental degradation, increased energy consumption, congestion, increased road accidents, travel delays, noise, and air pollution. Therefore, governments are spending huge amounts of their resources to encourage users to shift towards more sustainable and green modes of transport. BRT has gained popularity around the world, especially in developing countries because of its cost-effectiveness in contrast to expensive rail and LRT systems. As developing countries having inadequate capital resources; envisaging its benefits, BRT has become increasingly appealing for government investment. However, the majority of the BRT systems are relatively new, therefore, empirical evidence to assert their impacts on urban development, travel behavior, and economy is insufficient. Little research is apparent from the perspective of benefits associated with BRT development, especially on the following three important aspects. Firstly, inadequate research on BRT from the perspective of the user is evident. This is problematic because social benefits provided by the BRT serve as the utmost justification for government investment. Secondly, public transport investment is generally perceived by planners as a pure and exclusively mobility investment strategy while city-shaping impacts of BRT are mostly being ignored. Thirdly, access benefits underlined in wake of transit investment are capitalized into higher land values, and it becomes essential to quantify the land/property value effect of transport investment. Moreover, achieving sustainable cities, sustainable transport, and decent economic growth are major sustainable development goals (SDGs) delineated by the United Nations. Therefore, to enhance our knowledge, this dissertation examines the external benefits of BRT and attempts to quantify the travel behavior, urban development, and economic impacts that emerged after the implementation of BRT. This study focuses on the case of BRT in Lahore, Pakistan. Nevertheless this research could serve as a representative for developing countries and more specifically for those of South-Asia.

Since the association between BRT and land use complex, therefore, this research utilizes a more sophisticated approach i.e. actor relational approach to ascertain the constitution of different sub-systems (e.g. transport, urban development, and economy)

and their interrelation in the context of Lahore, Pakistan. This dissertation applies various quantitative and qualitative methods to discern the impacts of BRT. First, Binary logistic regression and analysis of variance (ANOVA) are utilized to determine the mode choice behavior of travelers in pre and post-BRT scenarios. Land use transformation, change in urban density are identified using map analysis. Variations in property values are estimated using a hedonic pricing model and geographically weighted regression. Interviews with different stakeholders helped to determine the factors that instigate these transformations and changes in the role and responsibilities of dominant stakeholders and the government.

The analysis of travel behavior indicated that BRT-Lahore has substantial impacts on the behavior of travelers. Besides a modal shift, BRT has also improved the choices for more environmentally friendly modes of transport, like walking. It is revealed that travelers' characteristics such as age, gender, occupation, education, income, travel purpose, vehicle ownership significantly influences the mode shift to BRT. The analysis of service-related attributes of BRT (e.g. time, costs, safety, reliability, comfort, integration) indicates that travel time, travel cost, and safety are the most important factors to influence the choice for BRT. Performance analysis delineated that a substantial difference was observed for the mean change in travel time between BRT and other modes. BRT users have less travel time compared to using a car, motorcycle, rickshaw, or other modes of transport. Also, a difference in mean change in travel cost was observed between BRT and car users. BRT is a preferred mobility alternative in Lahore because it is cheaper, faster, and safer compared to other modes of transport. Moreover, BRT in Lahore has substantially influenced the travel pattern of people.

The empirical investigation exploring urban development patterns in Lahore indicated that BRT, Lahore has the potential to stimulate land-use transformation. However, the extent of transformation is context-dependent. All the assessed BRT stations have shown an increase in commercial activities due to land-use conversion. The results indicate that all the areas have gone through land-use transformation, however, the extent of transition varies across the entire corridor. Change in population and building density is also evident in the study area. Population density has increased from 268 persons/acre to 299 persons/acre. An increase in building density for residential and commercial uses is observed majorly for all stations. In comparison to general development patterns in Lahore, areas around BRT have become increasingly appealing for residential and commercial activities. Thus, the observed land-use transformations and new activities indicate that BRT in Lahore is somehow successful in encouraging land-use transformation in its vicinity and that these benefits can be catered efficiently for the creation of a compact urban neighborhood.

The economic impacts of BRT being investigated in this dissertation mainly cover its impacts on property values, inward investment, and extension of the labor market. The hedonic pricing model (HPM) and GWR model is developed to investigate the relationship between property values and various independent variables (e.g. property attributes, neighborhood attributes, and accessibility). The hedonic model, as a global model, provides the average impacts of independent variables on property value, whereas GWR as a local model provides the opportunity to explore and map the local variations in property value premium. The results of the HPM indicate that the physical characteristics of the property like building age and number of bedrooms are significantly associated with an increase in property value. The width of the road as a neighborhood attribute is also associated with a higher premium; whereas, from accessibility attributes, only proximity to BRT station is significantly linked to the higher premium of the property. The mapping of local parameters shows a significant association between property value and proximity to the BRT station over the entire length of the BRT corridor. However, properties located in the north within 500 meters of Shahdara, Timber Market, and Qartaba chowk station gained a higher premium compared to properties located around other BRT stations. Probably the influence of downtown Lahore also applies here. But for the entire corridor, in general, a decline in the distance to the BRT station is associated with an increase in property value. Nevertheless, the value of premium varies over the entire BRT corridor.

The evidence from BRT-Lahore concerning inward investment indicated that an increase in economic activities is also witnessed along the corridor. Almost 22,000 million rupees (US $140 million) inward investment is detected after the implementation of BRT, which ultimately brought around 800 new employees. Thus, indicating that BRT, Lahore has significantly impacted its neighboring areas in terms of urban development, travel behavior, and economy. Besides providing mobility benefits, BRT until now is successful in generating land development and economic activities.

The analysis of the interrelationship between different impacts of BRT shows that this relationship between urban development, transportation, and economic development is continuous as they work in both directions. The development of any transportation system influences different aspects of urban and economic development. Similarly, urban development and economic factors also influence travel patterns and thus transport. In the future, when there would be more high-rise development along BRT, this will ultimately induce new demands for transport that would lead to an upgrade of the BRT services. This interrelation between urban development, transport, and economy can be explained through the actor relational approach (ARA). According to this approach, the interrelation between different human and non-human actors in a specific dynamic setting affects the conscious actors and locatable dynamic settings which further drives change. Hence, agencies and institutions co-evolve and they can drive towards a constant state of becoming and therewith towards a condition of innovation.

Nevertheless, the analysis of stakeholder's roles and responsibilities determines that there has not been much change after the BRT implementation. To handle the BRT operation and maintenance matters in and around Lahore, a new organization named Punjab Mass-transit Authority (PMA) has been established. The foundation of PMA has changed the role and responsibilities of few transport-related organizations, including the Lahore Transport Company (LTC) and the Traffic Engineering and Planning Agency (TEPA). However, no special policy measures were introduced to encourage transit-oriented development along the BRT corridor and the question of integrating land-use and transport development in the context of BRT remains the same. Although new building and zoning regulations are approved in 2020, it is too early to assess their impact in stimulating urban development in Lahore. But, in the new regulations, all the areas are opened for high-rise development. Futhermore, it was not focused to upgrade the infrastructure services and more focus is needed here. Given the limited financial resources, it is difficult to cater to the infrastructure requirements. Considering the current circumstance and financial constraints there is a need to focus on and utilize specific areas around transit corridors (e.g. those to BRT and Orange line) as a focal point for high-rise and high-density-based development.

Finally, a number of recommendations have been formulated in the framework to encourage transit-oriented development (TOD) in Lahore. Several departments/agencies are working for transport and land use development with overlapping jurisdiction. There exists poor coordination between these actors (actors related to transport and land use) which often results in negative spillovers and inefficiencies. First of all, there is a need to revamp the role of development and transport authority in the context of TOD. In the present fragment structure where responsibilities are distributed between various actors, one authority should take a leading role in integrating land-use and transport investment. In Lahore, urban development activities are mainly supervised by either the Lahore development authority (LDA) or municipal administration and in view of transport agencies such as Lahore Transport Company (LTC), Punjab Masstranist Authority (PMA), and Traffic Engineering and Transport Planning Agency (TEPA), the LDA should take the lead role in the planning and execution of the TOD plan. Strong political support to execute this TOD plan could play an important role in this regard. A transit-oriented plan can work on a mechanism of control and incentives and should be supplemented by a redevelopment plan, especially focusing on outdated areas.

We recommend amendments in zoning regulation for integrated urban development. Building and zoning regulations should be amended to encourage high-rise development. Higher density can accommodate new dwellings, which would help to counter urban sprawl in Lahore. Mobility nodes (i.e., BRT stations) can be promoted as places for higher rise development and density tapering as moving away from BRT. Higher density can be promoted by introducing tax exemption schemes and assisting land assembly requirements in the central areas. Policies encouraging land assembly could help in generating new development opportunities and a window for public-private partnerships. Nevertheless, besides density bonuses, local development authorities need to upgrade supportive infrastructure. In order to enhance the use of BRT in Lahore, it is recommended to ensure good accessibility to the BRT stations and to enrich the urban landscape by improving streetscape and sidewalks. The integration of BRT with other modes of transport is another important aspect, especially when non-motorized modes like walking and cycling are concerned. In Lahore, walking as a mode of transport has increased after the development of BRT. A good network of sidewalks and attractive streetscapes would help to achieve the objective of a walkable city and could increase multi-mode travel. Special attention should be given to design multiple urban spaces around the TOD. Policy measures, like restrictions on private vehicle use or congestion charging in the central area of the city, can induce a modal shift to BRT. Though this is not an easy task, encouraging public participation can help to achieve the goal of more sustainable transportation. Last but not the least, removing financial obstacles is another element of great importance when implementing TOD plans. First, public-private partnerships during land assembly can help to generate additional resources. Secondly, land value capture policy in the future could be utilized for this purpose.

The findings of this study can be considered before implementing other transit systems in Lahore that are delineated in the Lahore Urban Transport Master Plan. Several barriers need to be dealt with if future BRT/transit investments are to successfully shape the urban environment in developing countries around the world. Integration between transport investment and land-use policies can play a decisive role in realizing compact and sustainable neighborhoods. Although this research is situational, the general recommendations from this could be a useful tool for the planning of BRT systems in other Southeast Asian cities.

1

Introduction

1.1 Background

The world population is emergent at a rapid rate and most of this growth is conspicuous in cities. According to the United Nations, 55% (4.2 billion) of the world's population is living in urban areas which is expected to be 68% by 2050 (UN, 2018). Due to the rapid growth of the population, the necessity for diverse sources of mobility has also emerged in most cities of the world. Moreover, the pressure in densely populated urban areas has compelled people to live on the fringes of the city. Consequently, the spread of population at the urban fringes has amplified the need for mobility and most people use private cars as their mode of transport to fulfill their mobility needs. During 2018, in Europe, 83.3% of trips were executed using cars (Eurostat, 2020). In China, private vehicle use has been increasing drastically adding almost 1,000 new private vehicles in the traffic stream daily (Espitia, 2010). Similarly, the number of registered private vehicles in Mumbai, India has doubled in the last 10 years occupying 49% of the road space, while buses only share 2.2% of it. This situation is not different from what most developing countries are facing (TNN, 2019). This upsurge in automobiles has given rise to numerous problems including environmental degradation, increased energy consumption, congestion, increased road accidents, travel delays, noise, and air pollution (Kepaptsoglou, Milioti, Spyropoulou, Haider, & Karlaftis, 2020; Kogdenko, 2011; Lu, Hsu, Chen, & Lee, 2018; Motta, Da Silva, & Santos, 2013; Pucher, Korattyswaropam, Mittal, & Ittyerah, 2005; A. Zhang et al., 2019; Zhao, Zhan, Yao, & Yang, 2020). According to the report of IPCC (2007), the transport sector is responsible for 23% of greenhouse gas emissions which is the main cause of global warming.

Therefore, governments of developed and developing countries are spending huge amounts of their resources to encourage users to shift towards more sustainable and green modes of transport, for instance, electric vehicles, shared vehicles, public transport, etc. Different modes of public transport such as buses, trains, trams, Bus Rapid Transit (BRT), and Light Rail Transit (LRT) are in operation around the world. According to Beirão and Cabral (2007) buses are the most conventional mode of public transport running on regular roads with mixed traffic. But this mode is not preferable because of its discomfort, long travel time, and unreliability. On the other hand, train and light rail transit (LRT) are the types of public transport, which have fixed routes and sophisticated infrastructure and at the same time provide comfortable, frequent, and reliable services to its users. The cost incurred at the development of train, metro, and light rail transit system is massive and it is challenging in particular for developing countries to implement such systems on a wider scale because of scarce resources. Thus, to resolve these issues, developing countries are contemplating cheaper and sustainable transport options. Lately, BRT has transpired as a low-cost substitute to expensive LRT and Metro systems.

BRT has gained popularity around the world, especially in developing countries because of its cost-effectiveness in contrast to expensive rail and LRT systems (Satiennam, Jaensirisak, Satiennam, & Detdamrong, 2016; Suzuki, Cervero, & Iuchi, 2013; Wright & Hook, 2007). BRT has the ability to fulfill mobility needs and hence reduce congestion (Deng & Nelson, 2013; H. Levinson, S. Zimmerman, J. Clinger, & J. Gast, 2003). BRT stands in the middle between the traditional bus system and urban rail system, in terms of its cost and service quality. It helps to reduce travel time by segregating public transport (bus) operations from mixed traffic (Carrigan, King, Velasquez, Raifman, & Duduta, 2013). BRT provides travel characteristics similar to that of rail (e.g. comfortable, frequent, and reliable) at a much lower cost than that of a bus (Cervero, 2013a; Deng & Nelson, 2010b). The development cost of BRT is 10 times lower than that of the Metrorail system (Suzuki et al., 2013) and 4 times lesser than that of LRT (Cervero, 2013a). As developing countries having inadequate capital resources; therefore, envisaging its benefits, BRT has become increasingly appealing for government investment (Tabassum, Tanaka, Nakamura, & Ryo, 2017; Zolnik, Malik, & Irvin-Erickson, 2018).

"Bus Rapid Transit (BRT) is a rubber-tired transit system that delivers fast, comfortable, reliable, flexible, cost-effective and high-quality urban mobility through provision of partially/fully segregated right of way, regular or articulated buses, iconic stations with pre-boarding fare collection system and intelligent transportation systems elements to enhance user experience."

BRT is a high-quality bus service that has the benefits of reduced waiting and travel time, enhanced service quality, and reliability compared to traditional urban bus systems (Carrigan et al., 2013). BRT has several advantages over other transit systems; for example, it is less expensive and can be implemented much more quickly as compared to other rail systems. This feature of BRT makes it an attractive mobility alternative for politicians. Since the exclusive right-of-way is the prerequisite for a BRT system, it also offers the flexibility of future up-gradation (Zolnik et al., 2018).

The researchers suggest that investment in transit facilities has significant impacts on neighboring areas. These impacts may differ with the type (e.g. train, LRT, BRT), characteristics, and location of service (Mohammad, Graham, Melo, & Anderson, 2013). Such impacts of transit can be classified into travel pattern (Carrigan et al., 2013; Espitia, 2010), urban development (Jun, 2012; D. A. Rodriguez, Vergel-Tovar, & Camargo, 2016), economic (Banister & Thurstain-Goodwin, 2011; R. D. Knowles & Ferbrache, 2016), environmental (Hasibuan, Soemardi, Koestoer, & Moersidik, 2014; Kimball, Chester, Gino, & Reyna, 2013), and social impacts (Gleave & House, 2005; R. D. Knowles & Ferbrache, 2016). The externalities attached to BRT investment are important to consider as these can become a source to fund other transport projects. Thus, we move toward the mobility, urban, and economic rationale of transit investment.

1.1.1 The Mobility Rationale

The core aim of any transit investment is to influence the travel patterns of travelers and to shift them to green and sustainable modes of transport. Most of the studies indicated that investment in transit development helps to alleviate congestion in congested urban centers (Carrigan et al., 2013; R. D. Knowles & Ferbrache, 2016; Lane, 2008). In Mexico, BRT has played a role in stimulating modal shift from private vehicle to public transport (Espitia, 2010). Impacts of transit development on model shift were also witnessed by Ewing and Hamidi (2014) and Gleave and House (2005). Since the majority of the BRT systems are relatively new, therefore, empirical studies to asserting on their benefits are insufficient. Furthermore, limited research on BRT from users' perspectives is evident. This is problematic because social benefits provided by the transit system are the utmost justification for government investments (Venter, Jennings, Hidalgo, & Valderrama Pineda, 2018).

1.1.2 The Urban Rationale

The transport investment impacts on urban development is the second externality attached to transport investment which is being explored by the majority of the researchers (H. Levinson et al., 2003; Suzuki et al., 2013). Empirical evidence from Beijing, China shows that mass transit investments have exerted influence on land development (M. Zhang & Wang, 2013). According to Deng and Nelson (2010b), areas having access to a transit system have more propensity for redevelopment and new development. Alike other transit systems, BRT also has the potential to induce urban growth and urban development in a more sustainable way (Cervero & Dai, 2014). Cities like Ottawa, Adelaide, and Pittsburgh have witnessed substantial development activities around BRT stops (H. Levinson et al., 2003). The impacts on urban form and land development of BRT were also witnessed by Gakenheimer, Rodriguez, and Vergel (2011); and D. A. Rodriguez et al. (2016). The evidence indicated that investment in public transport infrastructure is not only a mobility investment, rather it has the potential to shape urban areas more sustainably. However, a strong link between transport policy and wider urban planning goals is the basis for the success of a transport investment project (Banister & Thurstain-Goodwin, 2011). Majorly the urban development impacts of BRT have been investigated in developed cities like Ottawa, Adelaide, etc., and more research is needed for the case of developing countries, where the city-shaping potential of transit investment is mostly seen as getting suppressed. Cervero and Dai (2014), also emphasized the need to explore the effects of BRT on city form, especially in developing countries.

1.1.3 Economic Rationale

According to SACTRA (1999), economic impacts can be evaluated based on its strength to stimulate inward investments, trigger fresh growth, the extension of the labor market, and land/property value increase. BRT Impacts on land price have been reported in Los Angeles (Cervero, 2004a), Bogota (Munoz-Raskin, 2010; D. A. Rodriguez & Mojica, 2008; Rodriguez & Targa, 2004), Boston (Kittelson et al., 2007), Beijing (Deng & Nelson, 2010b) and Brisbane (H. Levinson et al., 2003). Similarly, positive impacts on the property value of rail and light rail transit were observed (Cervero & Duncan, 2002b; Debrezion, Pels, & Rietveld, 2007; Pagliara & Papa, 2011). However, few studies have also shown depreciation in property values as a result of transit investment (Cervero & Landis, 1997; Ryan, 2005).

The economic effects of transport investments have also been investigated by Gleave and House (2005); R. D. Knowles (2012); and R. D. Knowles and Ferbrache (2016). A substantial inward investment was received adjacent to the light rail metro line in Orestad, Copenhagen (R. D. Knowles, 2012). The investment in transport can also influence job opportunities and employment productivity (Banister & Thurstain-Goodwin, 2011; Fan, Guthrie, & Levinson, 2012; Venables, 2007). Transport investment draws workers from the wider catchment area to the city centers and provides new opportunities for employment as seen in Copenhagen, Denmark. This project also drew employees from Sweden (R. D. Knowles, 2012). These shreds of evidence confirm the impact of transport investment on the economic development of urban areas. However, empirical evidence regarding the impact of BRT on economic activities including property values, inward investments, and the creation of jobs is limited.

1.1.4 The Social Rationale

Transport investment also affects the environmental and social credentials of an area. According to Espitia (2010), BRT can carry more people hence thereby reducing emissions per passenger. Curitiba city one of the pioneers of BRT, registered the lowest rates of ambient pollution (Espitia, 2010). Transmilenio in Bogota is considered a successful system for reducing environmental pollution. Only the first phase of Transmilenio helps to achieve a 28% decline in ozone levels ((Echeverry et al., 2005) by (Espitia, 2010)) and certified as Clean Development Mechanism Project in 2005-06 ((Grutter Consulting, 2008) by (Espitia, 2010)). From the social perspective, Gleave and House (2005), have argued that an increase in house prices may have resulted in the social exclusion of some people. Recently, Lucas (2004), has delved into designate social exclusion as a problem in the transport sector; the US and UK are even working on policies in this regard.

1.2 Problem Statement

Most of the research in the past focuses on establishing direct relations between transit investment (e.g. rail, metro, and light rail) and their corresponding impacts e.g. impacts on property values, development, environment, transport, etc. On the other hand, the literature on the impacts of BRT on travel behavior, urban development, and economy is limited and equivocal. Likewise, there is a need to explore the factors that stimulate travel behavior change, urban and economic development in developing countries. Moreover, very few studies have indicated the interrelationship between different impacts of transit investment. SACTRA (1999), indicated that investment in transport infrastructure generates opportunities for land-use change (e.g. residential to commercial) or redistribution that brings inward investment and further triggers economic development. Similar findings were explained by Banister and Thurstain-Goodwin (2011), who argue that firms tend to relocate themselves around transit services as a result of transport investment; ultimately supporting economic growth. But researchers mostly focuses on the economic impacts of light or heavy rail system while neglecting the economic benefits associated with BRT. Moreover, until now no study endeavors to capture and incorporate the economic benefits of BRT. The relocation of economic activities can enable urban growth in areas around the transit network. For example, in Vancouver, Manchester, Copenhagen, and Docklands London; investment in light rail attracts inward investment that catalyzes regeneration and renewal activities (R. Knowles & Ferbrache, 2014). Agglomeration benefits as a result of interaction between transport investment and economic growth were also identified (Venables, 2007). According to R. Knowles and Ferbrache (2014), transport produces certain activities (industrial/commercial activity); these activities assist in generating further growth. Banister (2007), mentions that a change in land use and mixed-use development around transport facilities encourages people to shift their mode of transport from private vehicle to public transport. The association between different impacts of transport investment identified by researchers is shown below.

Transport Investment → Urban Development → Economic Development
Transport Investment → Economic Development → Urban Development
Transport Investment → Urban Development → Travel Behavior

(Banister, 2007; Banister & Thurstain-Goodwin, 2011; R. Knowles & Ferbrache, 2014; R. D. Knowles, 2012; Mackett & Sutcliffe, 2003; Venables, 2007)

The arguments from various researchers portray interrelation between different impacts of transit investment to be linear but, in reality, it is more complex and relational. There are various actors, factors, and institutions involved that delineate this association. Despite these arguments, the nature of the interrelationship between different impacts of BRT investment has mostly been ignored in past studies. This work will first attempt to explore the travel behavior, urban development, and economic impacts of BRT and in the second stage, the interrelationship between these impacts. Moreover, the role of local planning agencies in reinforcing this relationship will be identified within Lahore, Pakistan as a case study. Local government/land use policies play an important role in integrating transport and land-use development (Cervero & Dai, 2014; R. D. Knowles & Ferbrache, 2016). Local government can play role in leveraging Transit-Oriented Development (TOD) by introducing zoning reforms, tax policies, supportive infrastructure, and land assemblage investments (Cervero & Landis, 1997). The identification of BRT impacts and the role of local government may help to establish an appropriate Transit-Oriented Development (TOD) plan. Based on these findings a policy framework for TOD will be established.

1.3 Research Questions

BRT impacts are referred to as; any type of transformation that emerges as a result of investment or operation of BRT. These impacts can be positive/negative and may include a change in land/property values, change in buildup area, change in employment/housing density, change in land use, etc.

The main research questions and their sub-questions for this dissertation are:

1. How does investment in Bus Rapid Transit (BRT) impact transport/travel behavior, urban development, and the economy?
   a. What are the impacts of BRT on people's travel behavior?
   b. What are the impacts of BRT on urban development?
   c. What are the economic impacts of BRT?
2. How are travel behavior, urban development, and economic impacts related to each other?

3. How do different institutions, actors, and factors evolve and interact with each other for the development of BRT?
4. What are the barriers to Transit-Oriented Development? and How to leverage Transit-Oriented Development (TOD) in developing countries to maximize the benefits of BRT investment?

1.4 Conceptual Framework

In this dissertation, actor-relational approach is used to explore the inter-relationship between transport, urban development, and the economy as shown in Figure 1. A two-stage framework has been used for this research. In the first stage direct impact of Bus Rapid Transit (BRT) investment on travel behavior, urban development and economy have been identified. The direct impacts of BRT investment and factors of importance are investigated using various statistical models (see chapter 4 for details). In the second stage, the association between different impacts of BRT investment has been identified using the actor-relational approach.

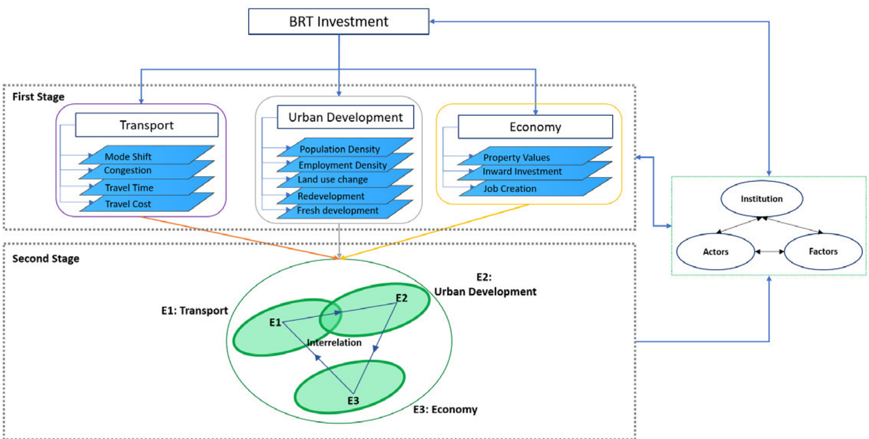


Figure 1 Conceptual Framework

1.5 Structure of Dissertation

Following the introduction, chapter 2 defines some basic concepts about bus rapid transit (BRT). Moreover, we will compare bus rapid transit and light rail transit to better understand the difference between the two systems. Following this, the worldwide and particularly South-Asia's, trends of bus rapid transit deployment are enlightened The succeeding chapter (theoretical framework) reports on the fundamental theories about space, system, and their interrelation including Actor-Network Theory and actor relational approach of planning. Afterward, in chapter 4 a detailed literature review is evaluated to identify the impacts of transport investment on travel behavior, urban development, and economy. Accordingly, a methodological framework and data collection mechanism is proposed for the study area. The variety of models used to identify the factors of importance for the system of travel behavior, urban development, and economy are hence discussed. Both primary and secondary data sources are used in this study. Primary data mainly includes field surveys, questionnaire surveys, and interviews. For secondary data government documents (e.g. transport and land-use master plans), rules and regulations will be consulted. This chapter also gives a brief description of Lahore's BRT system. In chapter 5, we will delve into the geographical location and urban hierarchy of the study area; including a description of the urban governance system in Pakistan. Chapter 6 to 8 consist of the empirical study and represents answers on the research questions above. In chapter 6, the transition in travel behavior and mobility pattern is investigated which is followed by an identification of factors that influence the mode choice behavior of travelers. Chapter 7 starts with an analysis of land use transformation that is transpired after the implementation of BRT. Further analysis is performed to discover the changes in urban density. Interview analysis is done to evaluate the determinants of land use transformation. In chapter 8, the economic impacts of transport investments are quantified by detecting the inward investment and extension of labor markets. Further, an analysis of the increase in property values is performed to determine the impact of BRT on the economy. The interrelation of inward investment with urban development and travel behavior is explored using interview data. Chapter 9 presents the institutional analysis focusing on the roles of various transport and urban development departments. This chapter also presents an analysis of building regulations. Lastly, chapter 10 presents the conclusions, leading to the formulation of policy recommendations for promoting sustainable development through BRT investment. Moreover, we will delve into the actor-relational conditions under which BRT investments would be the most promising or successful.

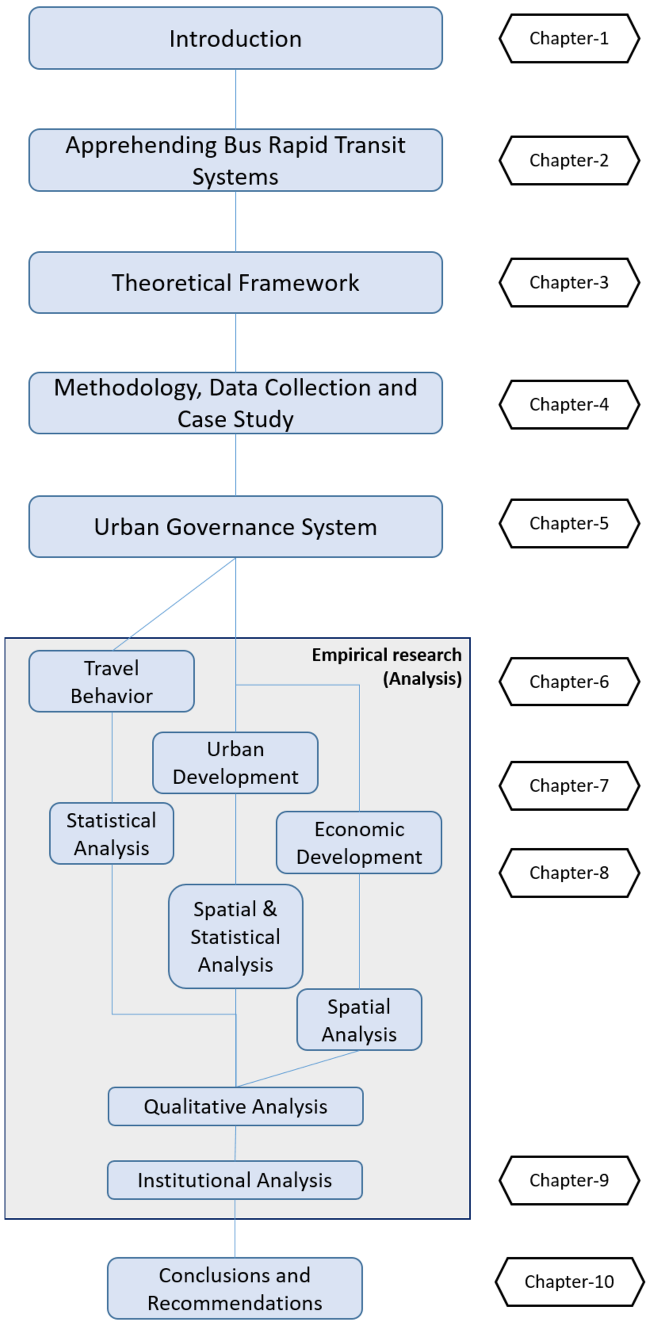


Figure 2 Structure of the Dissertation

2

Apprehending Bus Rapid Transit Systems

2.1 Introduction

Mobility, the liberty to travel, has always been an essential part of human life. As the world's population upsurges the need for diverse transportation modes also emerges. Today, different modes of transportation (e.g. car, train, bus) are being used for mobility. Generally, transportation can be divided into land, water, and air transportation. This research mainly focuses on land transportation. Several modes of transport are used in road transport such as bicycles, bikes, buses, cars, etc. Population growth worldwide has induced the demand for travel, as a result, the foremost evolution is being discerned in the use of private vehicles. According to Van Exel and Rietveld (2009), private vehicles are used for most traveled kilometers. As more vehicles packed the roadways, traffic congestion has a devastating effect on the quality of life. In the U.S. congestion caused travel delays of 3.7 billion hours in 2003 (APTA, 2007). Public transport has the potential to reduce traffic congestion. In America, public transportation services helped to save 1.1 billion hours of travel time. In the absence of public transport, travel delays would have increased by 27% (APTA, 2007). Besides, traffic accidents, travel delays, increased energy consumption, noise, and air pollution are the prevailing problems associated with transportation systems (Kepaptsoglou et al., 2020; Kogdenko, 2011; Motta et al., 2013; Pucher et al., 2005). In December 2013, European Commission introduced the concept of Sustainable Urban Mobility Plans (SUMPs) to address the undesired consequences of mobility. Moreover, public transport is reiterated as a pillar of a sustainable transport system in the European Commission's Action Plan (EU, 2017).

An urban public transportation system should work to provide a high level of transport service at a reasonable cost. It is imperative to define public transport as recent concepts of mobility like car-pooling and rider sharing have emerged as new modes of transportation. The term "public transport" is associated with traditional arrangements of mass transportation e.g. scheduled train or bus services. In this sense, Oxford Dictionary defines public transport as:

"A transport system (of buses, trains, etc.) that runs on fixed routes at set times and may be used by anyone on payment of a fare"

Figure 3 outlines a distinction between public transport and other modes of transport.

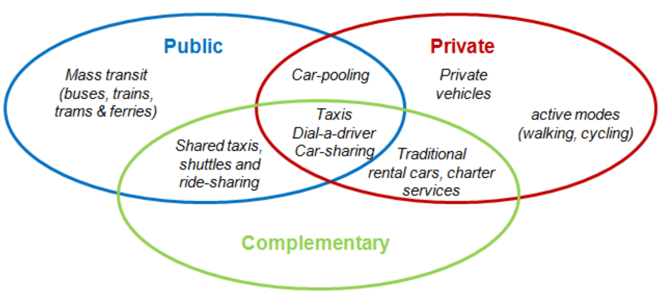


Figure 3 Relationship between difference type of transport services – *Source: (Cross, 2016)*

Public transportation (Land transportation) modes can broadly be categorized into two categories e.g. road and railways (Somashekar, 2013). Rail transport has the capacity to carry a large number of people and heavy articles over long distances. The public transportation modes which run on the principle of rail mainly include heavy rail, commuter rail, light rail, metro, cable car, aerial tramway, monorail, and automated guideway transit (APTA, 2007). Road transport modes have less capacity as compared to rail transport mode, but the construction and maintenance cost for these modes is much lower. Road public transport modes include bus, paratransit services, trolley bus (APTA, 2007). The recent mode that evolved under the road category includes bus rapid transit/high-quality bus or express bus. Besides these, in developing countries, there are also informal modes of public transport including rickshaw, qingchi, vans, etc. Generally, these are comprised of small-sized vehicles mostly operated by single individuals. Informal transport provides flexible and on-demand services to travelers (Cervero & Golub, 2007). The capacity of these modes ranges from 3 to 20 people per vehicle and are used for shorter distances (M. Kumar, Singh, Ghate, Pal, & Wilson, 2016). In most developing countries, they are the source of congestion, accidents, noise, and air pollution. These are also characterized by unsafe driving habits and overloading. Moreover, in most cases, they do not conform to government roles (Cervero, 2000a; Cervero & Golub, 2007; M. Kumar et al., 2016).

2.2 World of Bus Rapid Transit System

Bus Rapid Transit (BRT) is a system of public transportation developed in 1976. Curitiba, Brazil is ascribed as the pioneer of BRT (Cervero, 2013b). The concept of Bus Rapid Transit (BRT) was promulgated to enhance the customer experience and to provide them with improved transit service. Since that Latin American countries including Ecuador, Colombia, Mexico, Peru, and Chile have followed Brazil's model (Cervero, 2013b). After Curitiba, the BRT concept has widespread in the different regions. The North American cities such as Quito, Ottawa, Honolulu, Los Angeles, and Pittsburg have implemented this system. In Europe, this system is becoming common in cities in the United Kingdom (U.K.) like Leeds, London, Ispwich, and Reading. In Oceania, BRT systems are operational in the cities of Adelaida, Auckland, and Brisbane. BRT systems have been evidenced to be very cost-effective for public transportation. Bus Rapid Transit (BRT) has the flexibility to serve a wider geographical area (Levinson, Zimmerman, Clinger, & Rutherford, 2002) and can be implemented rapidly (Hidalgo & Carrigan, 2010; Zolnik et al., 2018). China has taken a leading role to implement BRT systems. China has developed 2,991 km of BRT as of 2005 (Velásquez et al., 2007). Figure 4 shows the development of BRT in different years. A list of BRT systems by region is given in Table 1.

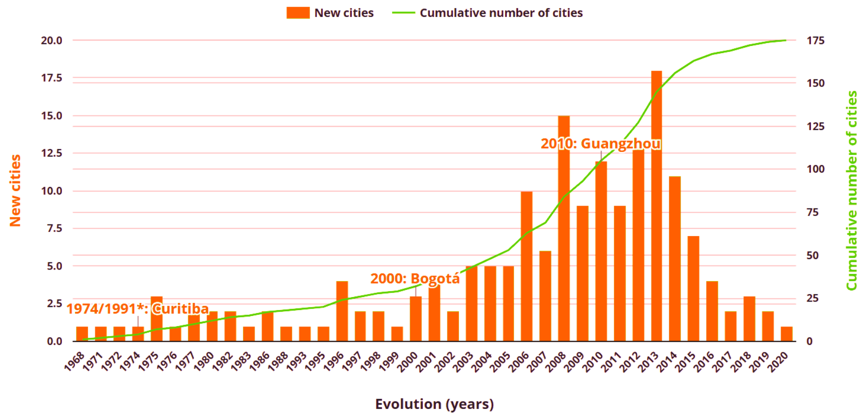


Figure 4 Evolution of BRT System – *Source: (BRTdata.org, 2020)*

Table 1 Global overview of BRT systems by Region

Regions	Number of Cities	Passengers per Day	Length
Africa	5	491,578	131
Asia	46	9,561,593	1,625
Europe	44	1,613,580	875
Latin America	56	20,909,541	1,840
Northern America	21	988,683	683
Oceania	5	436,200	109

Source: (BRTdata.org, 2018)

Today, BRT is operational in 177 cities around the world carrying around 33 million passengers per day (BRTdata.org, 2020). Most of this development is being observed during the last decade between 1991-2001 (Carrigan et al., 2013). Most of the BRT systems are operational in cities of Latin America (31.6%), Asia (25.28%), and Europe (25.28%) (BRTdata.org, 2020).

2.3 Development of Bus Rapid Transit in Asia

Asia is the most populous and largest continent covering around 30% of the total land area. The continent is home to 4.5 billion humans constituting approximately 60% of the world's population. Asia is famous for not only its population but also large and dense settlement patterns. Moreover, like other developing countries, urban transportation issues in Asia were partially addressed through financing roads (Kitamura & Mohamad, 2009). Unlikely, the supply of public transport services was not sufficient to cope with the ever-growing travel demand (A. A. Malik, 2013). These suboptimal policies shifted people from public transport to private vehicles which makes it inevitable to explore more sustainable and economically viable modes of transport. Many Asian cities have implemented bus rapid transit (BRT) as a sustainable transport mode to solve their transport-related problems (e.g. congestion, travel time delays, higher travel costs, etc.). In Asia, BRT is operational in 45 cities on 98 different corridors (see Figure 5). Asia has the highest number of kilometers (1,625) after Latin America (1840). Similarly, Asia has the second most number of passengers per day (28%) for BRT systems. However, when focusing on the specific case of South-Asia there are only two countries Pakistan and India who have implemented some kind of bus rapid transit system. BRT is operational in 8 cities of India with 12 corridors, whereas in Pakistan 3 cities are providing BRT services including Lahore, Islamabad-Rawalpindi, and Multan.

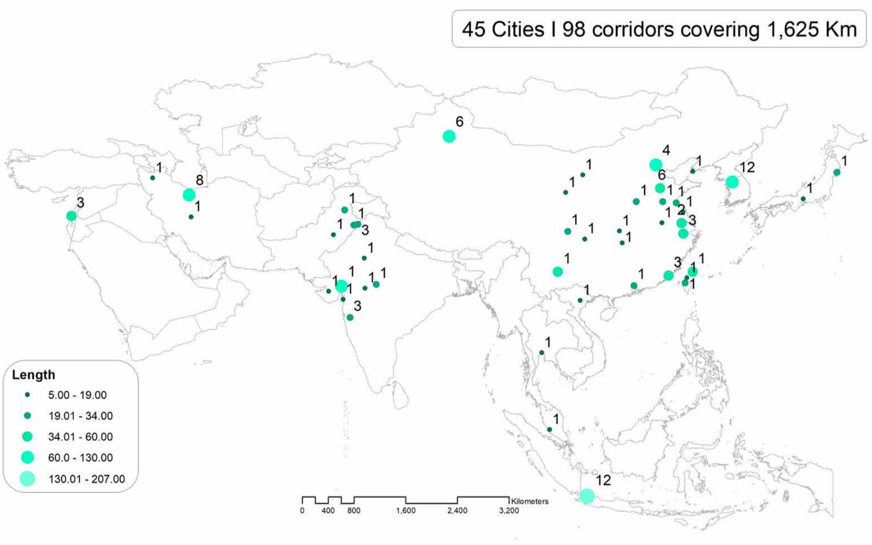


Figure 5 Location of BRT system in Asia Data – *Source: (BRTdata.org, 2020)*

However, besides these developments, there remains a debate about BRT's service attributes as it encompasses a wide range of services. Moreover, various terms are interchangeably used in literature for the same mode of transport. For example, the term high capacity bus system, metro-bus, high-quality bus system are used by Wright (2002) as an alternative name to BRT. Throughout Europe, various terminologies are used: In France (BHNS-'Bus à Haut Niveau de Service'), in the Netherlands as "high-quality public transport" and in Spain and Germany with the name "Metrobus".

All these services are collectively branded BHLS-Bus as High Level of Service (Finn et al., 2011). In some cases, BRT is also known as Bus Semi Rapid transit-BST Vuchic (2002). Thus, a clear definition of BRT is missing (Cervero, 2013a) therefore, most of the time many other bus services are confused with BRT. There also remains a contradiction among different researchers while sub-dividing BRT systems into two categories based on Right Of Way (ROW). Cervero (2013a), sub-divided the BRT system into Full-BRT and BRT-lite depending on the ROW parameters and technologies. Whereas, Wright (2002), divides the BRT system into three different categories such as BRT-lite, BRT, and Full

BRT. Thus, BRT and its classes needed to be defined based on common criteria for a better understanding of the BRT system and a comprehensive comparison of the BRT system with other transit modes, like light rail transit (LRT). The literature available on bus rapid transit is fuzzy and needs further clarification for proper implementation of the BRT concept. The implementation of BRT around the world and especially in developing countries. Moreover, its prominence as a cost-effective alternative to the expensive metro rail systems, makes it essential to accurately define BRT and its different type. In this dissertation BRT system and its various categories based on right of way (ROW) have been defined.

2.4 Defining and categorizing Bus Rapid Transit

BRT does not reflect a single image or meaning; instead, it reflects a variety of applications, ranging from simply providing, marking, or infrastructure improvement to regular bus services running with mixed traffic to completely segregated systems. Following are the terms used by researchers in the literature to define BRT.

In the Transit Metropolis, BRT is defined as a form of "adaptive transit" – best able to serve largely market driven, spread out development patterns (Cervero, 1998).

BRT is a mode of Transportation that combines the quality of rail transit and the flexibility of buses (Thomas, 2001 referred by Wright and Hook, 2007).

Vuchic (2002) referred to BRT as Bus Semi rapid Transit-BRT and defines it as a "*bus system operating on ROW category B, with preferential signals, separate stations with fare collection prior to boarding, regular or articulated buses and other amenities line performance*" (Vuchic, 2002, p. 1).

According to Wright (2002), "*BRT is high quality, customer-orientated transit that delivers fast, comfortable and cost-effective urban mobility*" (Wright, 2002, p. 1).
Henry and Litman (2006), describe "*BRT consist of high-quality bus services, often on grade separated busways, and which generally offer intercommunity express services, usually complemented by improved local services and other amenities*''. (Henry and Litman, 2006 p. 6).

For Kittelson et al. (2007), "*BRT is a flexible, rubber-tired form of rapid transit that combines stations, vehicles, services, running ways, and ITS elements into an integrated system with a strong identity*".
According to Wright and Hook (2007), " *Bus Rapid Transit (BRT) is a high quality bus bases transit system that delivers fast, comfortable and cost effective urban mobility through the provision of segregated right of way infrastructure, rapid and frequent operations, and excellence in marketing and customer service*" (Wright and Hook, 2007, p. 11).

Ruffilli (2010), defines BRT as "*a rubber-tired rapid transit service that combines stations, vehicles, running ways and a flexible operating plan into a high quality, customer focused service that is fast, reliable, comfortable and cost efficient*". (Ruffilli, 2010, p. 2).

For Hidalgo and Carrigan (2010), Bus rapid transit (BRT) is a high-quality, efficient mass transport mode, providing capacity and speed comparable with urban rail (light and heavy rail). BRT is a flexible service that connects to stations, buses, exclusive and segregated busways, and intelligent transportation system elements into an integrated transit system.

According to Carrigan et al. (2013), BRT provides a higher-quality service than traditional urban bus operations because of reduced travel and waiting times, increased service reliability, and improved user experience.

The BRT standards define BRT as a "*bus-base rapid transit system that can achieve high capacity, speed, and service quality at relatively low cost by combining segregated bus lanes that are typically median aligned with off-board fare collection, level boarding, bus priority at intersections, and other quality-of-service elements (such as information technology and strong branding)"* (ITDP, 2016a).

It is important to mention that BRT and BHLS concepts are often confused and questioned. The absence of exclusive ROW makes it uncertain to label BHLS as BRT. But when these systems are compared with BRT systems of the United States, the realization of exclusive ROW remains limited. However, the basic concepts of BRT and BHLS service are the same; that is to provide reliable and fast bus service. Moreover, according to Finn et al. (2011), numerous BHLS systems in Europe approach the definition of BRT-Lite, and most of the new systems correspond to BRT.

All the definitions stated above cover two main aspects e.g. infrastructure and service quality. These define BRT as fast, comfortable, flexible, cost-effective, reliable, integrated, and high-quality bus service provided through the provision of segregated/ grade-separated right of way. None of these encompasses all the aspects of the BRT system. Definition provided by Wright and Hook (2007), seems to be a precise one however, this definition does not cover all the basic concepts of BRT. The author claims the BRT system, as running on a fully segregated right of way (category-A) which is not accurate. Indeed, many systems not having fully segregated right of way are also considered as BRT e.g. BRT orange line in Los-Angeles. Moreover, the definition does not say anything regarding the provision of stations and fare collection systems. Similarly, Hidalgo and Carrigan (2010), attribute BRT service as having the exclusive and segregated right of way. Therefore, there is a need to re-frame one comprehensive and precise definition of bus rapid transit that can cover a wide range of BRT services around the world.

Secondly, it is also significant to narrate different types of BRT systems and to categorize them based on one common criterion. According to Vuchic (2002), transit modes can be categorized based on three characteristics.

- Right of way (ROW)
- System Technology
- Type of Service

Right of way (ROW) is the most important criterium to classify transit modes (Vuchic, 2007); system technology is strongly influenced by the ROW. Moreover, in the BRT planning guide, Wright and Hook (2007) indicated the provision of a segregated right of way for a system to be considered as BRT. According to BRT standards delineated by ITDP (2014), a BRT should have delineators only or colorized pavement over 75% of the corridor length.

Three different types of ROW classes (A, B, and C) are defined.

- ROW A: the transit services having fully separated ROW, without the intervention of any other vehicle. This class is also referred to as grade-separated;
- ROW B: the transit services having partially separated right of way which is physically segregated by barriers, curbs, grade separation, and having regular street intersections;
- ROW C: the transit services run on common streets with mixed traffic.

(Vuchic, 2007)

Vuchic (2007), classified transit modes into three generic classes based mostly on the ROW they use. Transit modes operating with mixed traffic (ROW-C); also known as street transit or surface transit. Semi-rapid transit modes are those operating on ROW category B. Semi-rapid transit modes also use ROW A and C on some sections of their route. Light rail transit (LRT) mostly operates on ROW-B. The third class of transit modes that operate on ROW category A is named Rapid transit.

Regular bus, express bus, bus rapid transit (BRT), light rail transit (LRT), metro, commuter rail, heavy rail can be comprehended in most of the cities around the world as modes of public transport that operates on varying ROW categories. Conventional buses operate virtually in every city. Buses are capable of transporting numerous passengers at very low costs (Somashekar, 2013). Bus service can be introduced/modified easily. Buses can operate on regular streets with other traffic (ROW-C). Regular bus operation only requires the acquisition of vehicles, garage, maintenance, and organization of service. Regular buses are the most economical and labor efficient as one bus can carry 50-150 passengers. The distance between two bus stops in case of a regular bus operation is 250-400 meters (Vuchic, 2002). Regular buses are not encouraged, as people perceive them as a source of discomfort, waste of time, and unreliable (Pojani & Stead, 2015). Bus service can be upgraded to offer a higher service level. The express bus is a transit service, which operates mostly on separated lanes of freeways or roadways, with stop spacing further away from each other compared to the conventional buses (Vuchic, 2002). Express bus services have fewer stops as compared to normal bus service which makes its operation quicker. Moreover, express bus services have the facilities of pre-boarding fare collection, wireless internet, and comfortable seating (Wikipedia, 2018). Express bus service has higher fares than regular buses and competitive with private vehicles. Express bus service often operates between major regional centers and city centers (Vuchic, 2002). Bus Rapid Transit (BRT) is a system of public transportation developed in Curitiba, Brazil in 1976. BRT provides higher speed, capacity, reliability, and performance than regular buses (Vuchic, 2002). The attributes which distinguish BRT from regular bus operation are upgraded ROW, large station space, signal priority, fare prepayment, and other elements of the intelligent transportation system (Puchalsky, 2005).

Rail transit epitomizes several transit modes that operate on rail technology; steel wheels on steel rails. Major services included in this category are light rail transit, metro, commuter/regional rail (Vuchic, 2002). Usually, rail transit services have higher performance than regular buses in respect of speed, capacity, and reliability. Metro is the form of rail transit that has a fully separated right of way (ROW-A). Metro systems are being operated in more than 100 cities. Metro system is provided when demand surpasses the capacity of LRT and BRT and higher speed is needed (Wirasinghe, Kattan, Rahman, & Hubbell, 2013). Metro has more speed than LRT which may range from 30 km/h to 60km/h and have the capacity from 20,000-80,000 people per hour. Such systems are operational in cities like Washington, Tokyo, Hong Kong, and New York. Regional/Commuter rail provides access between central city and suburbs and offers capacity between 15,000-40,000 people/hr. Such a system can compete with private cars because of their speed, comfort, and reliability. These operate on ROW-A. The largest rail systems are operational in mega-cities such as Paris, Tokyo, New York (Vuchic, 2002). Light Rail Transit (LRT) is a mode of transport that straddles between regular buses (low capacity) and metro rail (heavy capacity). LRT line capacity may vary from 3,000-20,000 persons/hr. LRT usually runs on ROW-B (Vuchic, 2002). Infrastructure and equipment used for LRT are the same but are less massive than typical rail modes i.e. heavy rail, commuter/regional, and metro rail (FICCI, 2013). According to Henry and Litman (2006), light rail transit generally comprises of medium size trains that are deployed to provide services in local areas using a combination of mixed and grade-separated rail lines. LRT compared to metro rail has short train length, segregated right of way (ROW) is not necessary, and sometimes may have road level crossings (FICCI, 2013). A comparison of different modes of public transport is given in Table 2.

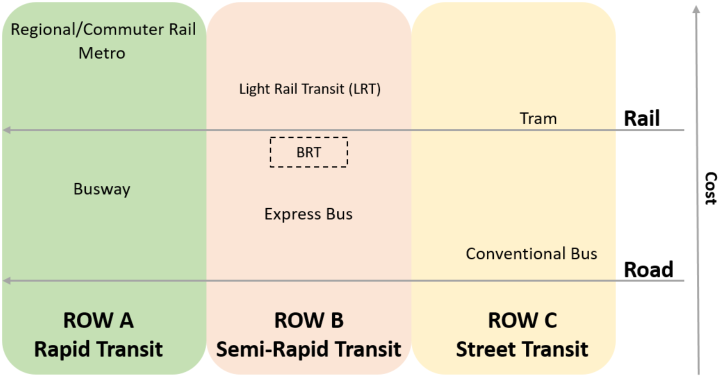


Figure 6 Mode Category based on ROW – *Source: (Adapted from Vuchic, 2002)*

Table 2 Comparison of Mode of Public Transport

	Bus	BRT	LRT	Metro	Commuter Rail
Right of Way	Mixed	Shared or segregated lanes	Shared or Exclusive	Exclusive lane	Exclusive lane
Cost	-	$100,000-$22 million per km[1]	$5 -$48 million per km	$60-$70 million per km	-
Network	Local	Local or Regional	Local		Regional or Local
Maximum Speed (Kilometer per hour)		60-70 kph[2]	40-100 kph	70-100 kph	127 kph
Maximum Capacity (passengers/vehicle unit)	60-80	120-270	170-280	240-320	-
Maximum Capacity (passengers/vehicle coupled)	60-80	120-270	240-360	1000-2400	-
Construction time	-	Less than 18 months	2-3 Years	4-10 Years	-
Vehicle Propulsion	Diesel	Diesel	Electric	Electric	Electric or Diesel
Station Spacing	250-400 meters	Less than 1500 meters	400-1600 meters	-	Several miles
Demand Requirement	500-5,000 pphpd[3]	3,000-45,000 pphpd	5,000-12000 pphpd	30,000-80,000 pphpd	-

Source: (Deng & Nelson, 2011; Espitia, 2010; Hensher & Golob, 2008; Levinson et al., 2002; RTD, 2016; Ruffilli, 2010; Vuchic, 2002, 2005; Wright & Hook, 2007; M. Zhang, 2009)

[1] kilometer [2] Kilometer per hour [3] passenger per hour per direction

Right of Way (ROW) is an important criterion for the categorization of transit modes. Figure 6 is a pictorial representation of the transit mode category being suggested by Vuchic (2007), based on the ROW. Different modes are categorized based on the ROW they use.

This categorization of Vuchic (2007) is simple and needs modification as different classes of modes have emerged over the past few years (e.g. BRT-lite and Full BRT). There are different public transport bus systems around the world, which provide high-quality service but are not fully covered under the definition of BRT like BRT in Lime (Peru). Basic “busway” corridors like Lima (Peru) do not have the standards of BRT but helps in the conceptualization of BRT. In cities like New York, Los Angeles, and Perth, public transport is given priority by providing basic busways running along freeways. Busways help to provide rapid access between city centers and suburban areas. Though these systems help to improve travel time, they lack other basic characteristics of BRT such as off-board fare collection, use of intelligent transportation system, etc.

Figure 7 demonstrates different types of BRT systems. Three different types of BRT systems are presented by Wright and Hook (2007). These include BRT-lite, BRT, and Full BRT. The difference between BRT-lite and BRT is the provision of the segregated busway. In this division, the difference between BRT and Full BRT is not clear with respect to the right of way. On contrary, Cervero (2013a), categorized BRT into two categories BRT-lite (also called low-end BRT) and BRT full (also called high-end BRT) based on its characteristics as shown in Table 3. The main difference between high and low-end BRT is the existence of a segregated ROW. For a high-end BRT, it is necessary to have an exclusive ROW for the majority of its system length whereas, a low-end BRT can operate in mixed traffic. Other factors that distinguish BRT from other bus services (e.g. express bus/regular bus) are the presence of high-quality bus shelters, pre-boarding fare collection, and the use of advanced ITS (intelligent transportation system) technologies.

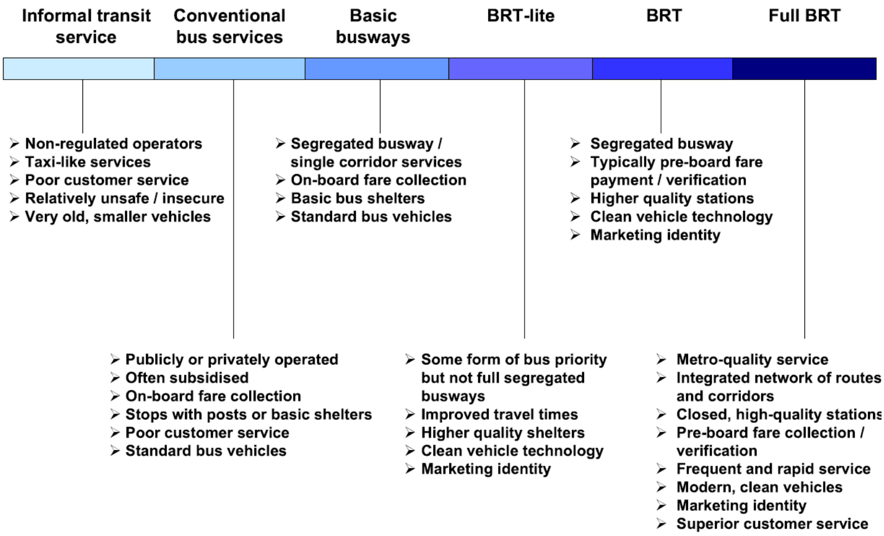


Figure 7 Tier based Public Transport Services – *Source: (Wright & Hook, 2007)*

Table 3 Comparison of BRT-Full and BRT-Lite

Service Type	BRT Full/ High-end BRT	BRT-Lite/ Low-end BRT
Running Ways	Segregated Bus lane; maybe grade-separated	Operate with mixed traffic
Stations/Stops	High-quality bus station with controlled transit centers	Sometimes stops with shelter, lighting, seating, and passenger information
Service Design	Integrated and more frequent service	Traditional service designs
Fare Collection	Pre-boarding fare collection; multi-door loading and use of smart cards	Traditional method
Technology	Passenger information system; automated vehicle location (AVL) and traffic signal preferences	Limited technological application

Source: (Cervero, 2013a)

In both categories presented above BRT-lite is demonstrated quite alike, operating with mixed traffic. Whereas Wright and Hook (2007) proclaimed that a system should have segregated right of way to be labeled as BRT. Similarly, ITDP (2014), recommended that a system should have delineators only or colored pavement over 75% of the corridor length to be labeled as BRT. Therefore, the bus system not having a separate ROW and running with mixed traffic cannot be considered as BRT. Such systems can be named *"Enhanced bus service"* (Wright & Hook, 2007). Nevertheless, there is a need to categorize BRT systems; for a proper understanding of decision-makers and market identity of the BRT system. Figure 8 gives an overview of different rail and road public transport modes based on the ROW category particularly focusing on bus rapid transit (BRT). Based on previous literature and right of way service use BRT can be classified into two distinct categories BRT-lite and full BRT. However, along with the provision of other elements of BRT such as pre-boarding fare collection, high-quality stations, and use of intelligent transportation technologies; ROW category B is the basic requirement for a system to be labeled as BRT-lite. Vuchic (2007), labeled transit modes running on ROW category B as semi-rapid transit and BRT as Bus-semi rapid transit. So, Bus-semi rapid transit terminology can be used for BRT-lite. BRT system operating on ROW category A can be termed as Full-BRT. As full BRT falls under the category of rapid transit so the term "rapid" can be used for such systems. As per the BRT standard defined by ITDP, 2014 full 8 points are given to the BRT system fulfilling the following criteria:

- Dedicated lanes and full enforcement or physical segregation applied to over 90% of the busway corridor length

Therefore, the same principle can be applied to label a system as Full-BRT. This categorization is only based on the ROW a service uses. Nevertheless, a system needs to have other characteristics of BRT such as pre-boarding fare collection, high-quality stations, and use of intelligent transportation technologies (e.g. Automatic vehicle location, passenger information, etc.) along with ROW B or A for BRT-lite and Full BRT respectively. Figure 8 represents the new categorization of bus rapid transit systems based on the ROW. It can be seen that with full segregation of ROW, the capital cost of the BRT system increases but it's still less when compared with rail transit systems.

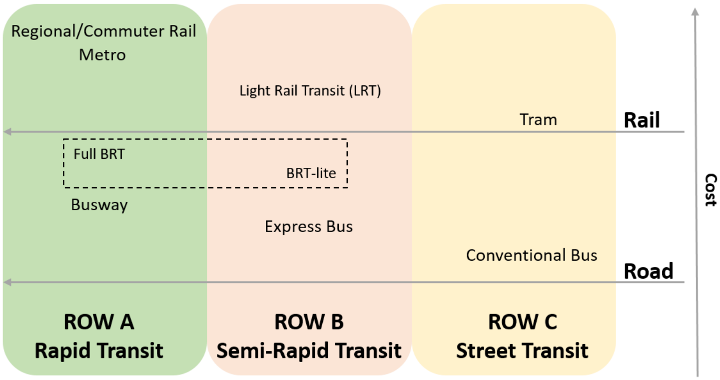


Figure 8 Public transport Mode ROW Category

Last but not the least, in all the previous studies BRT is always described in comparison to rail transit systems. For example, Shah et al. (2020), describes a bus rapid transit system as the one that matches the performance and features of rapid rail systems. Moreover, BRT is often compared with LRT (Lopez Lambas & Giuffrida, 2017; Vuchic, Stanger, & Bruun, 2012). Therefore, it is inevitable to make a comprehensive comparison between BRT and LRT. This will help policymakers and decision-makers as they often need to choose between different transit (BRT and LRT) systems. A comparison of BRT and LRT is drawn in the following section.

2.5 A Comparison of Bus Rapid Transit (BRT) and Light Rail Transit (LRT)

Numerous cities around the world are expanding their public transport network in response to rapid urbanization and a substantial increase in traffic congestion. Most governments especially in developing countries have limited resources to deploy rail transit services. This inverse relation of limited resources and huge public funding for transit services has made it crucial to finance public transport. Accomplishing an effective transit system is vital for attaining efficient use of cramped public resources. Governments and transport experts are considering new public transport service opportunities which provide people with efficient and sustainable modes of transport at lower costs. Over the last few decades, Light rail transit (LRT) and Bus rapid transit (BRT) have emerged as new modes of public transport that provide services at a much lower cost than heavy rail systems (e.g. train systems like MRT, metro, etc.), and at the same time are more reliable and efficient as compared to regular buses. Recent developments of BRT and LRT in cities have instigated the discussion on the comparative advantages and disadvantages of both systems (Rizelioğlu & Arslan, 2020; Vuchic et al., 2012). Currently, BRT is operational in 177 cities (BRTdata.org, 2020) whereas, LRT is operating in 389 cities around the world (UITP, 2019). BRT and LRT are often compared pertaining to their speed, performance, and cost. It is pivotal for decision-makers to choose between LRT and BRT because some critics proclaim rail investments as extravagant (O'Toole, 2005); whereas, few researchers found capacious impacts of rail transit system (Bento, Cropper, Mobarak, & Vinha, 2005). Diverse arguments have been bestowed by proponents of BRT and LRT to support these systems. According to Van der Bijl, Van Oort, and Bukman (2018), a high-quality bus network can approach/match the performance of light rail to some extent. Research in the past has tried to compare the performance of LRT and BRT (Currie & Delbosc, 2013; Rizelioglu & Arslan, 2016) based on capital cost (Bruun, 2005; Tirachini, Hensher, & Jara-Díaz, 2010), ridership (Stutsman, 2002), and emission (Puchalsky, 2005). According to Wright and Hook (2007); low cost, rapid implementation, operational flexibility, and high performance (speed/reliability), are the reasons for the rapid expansion of BRT systems around the world. Perceiving the recent developments of LRT and BRT, a more comprehensive comparative analysis between the two is inevitable. A detailed comparative analysis between BRT and LRT is flourished in this section based on capital cost, capacity, infrastructure, ridership, and service attributes.

2.5.1 Capital and Operational Cost

Capital and operational cost play an important role in the selection of specific transit services in response to limited resources available for local governments. Researchers have proclaimed that BRT development costs much lower than LRT (Hidalgo & Carrigan, 2010; Nikitas & Karlsson, 2015; M. Zhang, 2009). Typically, the development cost of a BRT system is 4 to 20 times less than LRT (Cervero, 2013a; Wright & Hook, 2007). The capital cost for BRT can range from less than $100,000 per km (BRT operating on the existing street way) to $22 million per km (full segregated BRT). Whereas, the capital cost for the construction per kilometer of LRT may vary from $ 5 million (on-street LRT) to $ 48 million (full grade-separated) (Ruffilli, 2010). Based on these findings of the lower capital cost of BRT, it is asserted that the BRT system can compete with rail-based transit systems (Cain, Flynn, McCourt, & Reyes, 2009).

Generally, capital costs include costs for stations, land acquisition, traffic signals, park & ride facilities, special vehicles (if needed), and maintenance facilities (Calgary, 2002). Land acquisition cost is usually lower for LRT systems because BRT vehicles possess more width and consequently require a wider runway (Hidalgo & Carrigan, 2010), but it largely depends on the local conditions and physical characteristics of the system. Figure 9 shows the capital development cost for various BRT and LRT systems around the world. It can be observed from all the cases that the development cost of BRT is much lower than that of the LRT system.

Usually, LRT and BRT systems require depots. However, in the case of an LRT system, a special depot linked with the system through rail tracks is required that eventually enhances the capital cost. BRT depot does not essentially require to be connected to the BRT corridor and can be placed anywhere in the vicinity of the corridor. In some cases, an existing bus depot can be utilized (ITDP, 2018).

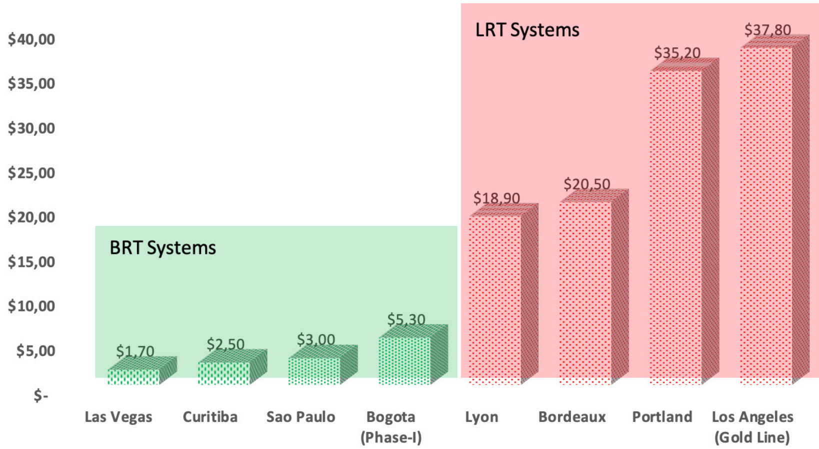


Figure 9 Capital Costs for various BRT and LRT systems – *Source: Adapted from (Wright & Hook, 2007)*

Although the experience has shown that capital investment of BRT is lower than LRT, but it is not obvious that this association will hold for operating cost too. According to Ruffilli (2010), BRT system advantages are not clear in the case of operating costs. Operational cost includes fixed operation costs (salaries of staff), repayment of capital (vehicle depreciation cost), and variable operational costs (fuel, lubricants, and maintenance) (Wright, 2002). According to Bruun (2005), the operating cost of BRT and LRT is lower than that of the regular buses but the difference between the operating cost of BRT and LRT is not clear. However, few researchers have tried to figure out the difference in operating costs for BRT and LRT. For example, Tirachini et al. (2010), indicate that the operating cost of BRT is lower than LRT. In Calgary, a higher cost per revenue hour was observed for LRT ($113) compared to BRT ($49) (CT, 2002). The orange line (BRT) in Los Angeles, in terms of operating cost efficiency, costs less as compared to the Gold line (LRT) i.e., 59% less for every boarding, 58% less for annual revenue service hour, and 50% less for each passenger mile (Flynn, Thole, Perk, Samus, & Van Nostrand, 2011). However, it is not consistent with the findings of Bruun (2005) and Perth (2014). Figure 10 and Figure 11 demonstrate a comparison between LRT and BRT operating costs in six cities of the United States which provide both LRT and BRT transit services. Figure 10 displays the comparison of cost per revenue hour. The operating cost for BRT includes fuel, driver's salaries, maintenance cost of the vehicles and runway. For LRT the operating cost includes cost for electricity, driver's salaries and maintenance cost of the vehicles and track. Figure 10 shows that, in most of the cases (in five cities) BRT outperforms LRT considering cost per revenue hour. Figure 11 shows the comparison of cost per passenger for various LRT and BRT cases. This illustrates the total expenses of transport of an individual per trip. From the compared cases, four out of six BRT routes have lower operating expenditure per passenger.

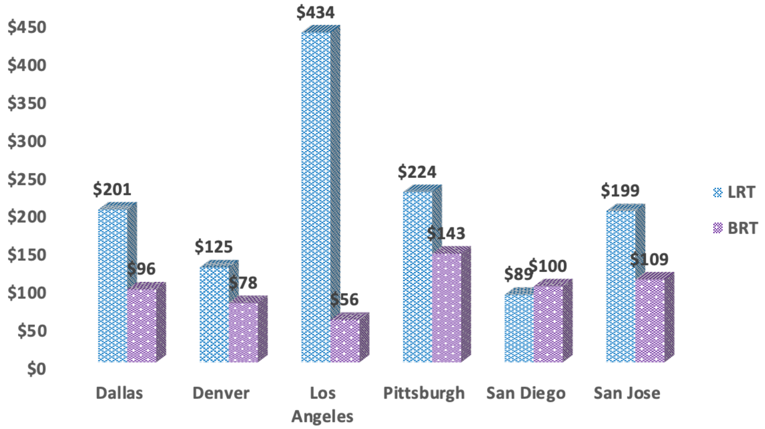


Figure 10 Comparison of Cost per Revenue Hour for LRT and BRT – *Source: (GAO, 2001)*

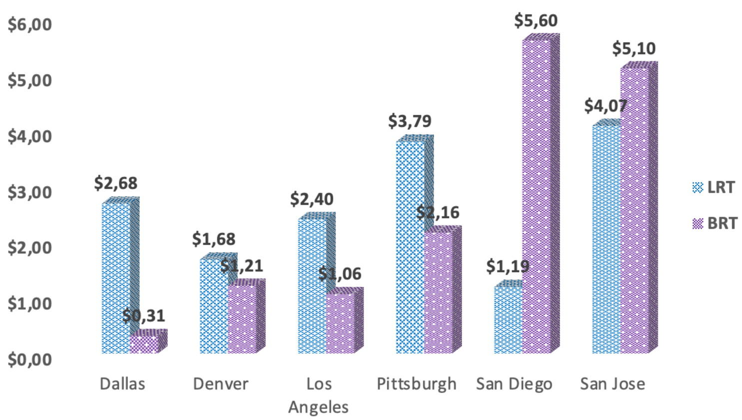


Figure 11 Comparison of Cost per Passenger for LRT and BRT – *Source: (GAO, 2001)*

Tirachini et al. (2010), compares the performance of BRT, LRT, and Heavy rail using a microeconomic model while considering four operational elements: waiting time cost, access time cost, operator cost, and in-vehicle time cost. Results discovered that the frequency provided by BRT is higher, which implies less access time and waiting cost for BRT users. A BRT system has advantages over the rail for all four operational elements. But these results only hold for lower demand levels. In view of Bruun (2005), LRT is preferred whenever the operational cost is concerned because rail technology requires the addition of cars to accommodate peak hour demand whereas in the case of BRT separate driver and vehicle is required. However, experiences show that BRT provides the benefits of the self-sustainable operation, such as BRT in Bogota which started in 2000 was entirely funded by fare collection excluding initial infrastructure costs. In Curitiba, BRT is performing self-sufficiently for above 25 years (Matsumoto, 2005). For lower demands level, BRT provides better operational services such as less waiting and access time.

2.5.2 Capacity

Transit capacity can be defined either through transit vehicle capacity or passenger capacity. Transit vehicle capacity can be expressed in terms of vehicles per hour per direction, whereas passenger capacity can be expressed in terms of passengers per hour per direction (Wirasinghe et al., 2013). According to Ruffilli (2010), BRT passenger capacity is lower compared to LRT as noted by Perth (2014), LRT systems have the capacity to attract up to 30% more passenger volume. Contrarily, the opposite can be pragmatic under high saturated conditions like Manila, where LRT capacity is less than several BRT systems (Kiihn, 2002). Similarly, Wright and Hook (2007), specify that BRT represents a wide range of capacity options that may surpass the capacity of LRT as shown in Figure 12. However, one may claims that the capacity presented here is a theoretical capacity overestimated by the proponent of BRT. and has nothing to do with reality. Therefore, it is important to apprehend a comparison for the capacities achieved by different BRT and LRT systems around the world.

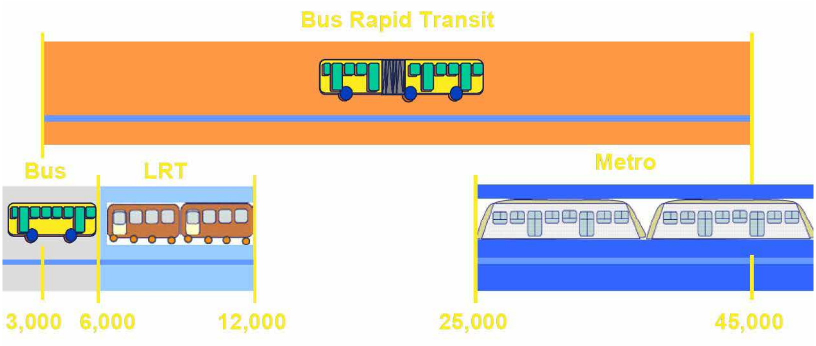


Figure 12 Public Transport Capacity (Passengers/hour-direction) – *Source: (Wright & Hook, 2007)*

The analysis of capacity (PPHPD-passengers per hour per direction) shows that there is no LRT line either in Canada or the U.S that approaches the volume of 10,000 except Muni Metro subway in San Francisco which is shared by seven routes and Greenline subway in Boston. In Europe, an achievable capacity of 20,000 (PPHPD) is reported nevertheless, at these capacity levels system is often called light metro, U-bahn, or pre-metro having many characteristics of heavy rail (P. Kittelson, Quade, & Hunter-Zaworski, 2003). In Boston, during peak hours light rail transit carries 9,600 PPHPD (Hanson & Giuliano, 2004). LRT line in Addis Ababa transport 15,000 PPHD (Gazette, 2015). Two LRT lines in Madrid, ML1 and ML2 carry 13,425 and 10,137 passengers per hour per direction respectively (F. J. Calvo, de Oña, Arán, & Nash, 2013). The LRT in Sydney has the capacity of 13,500 passengers per hour per direction (Hensher & Golob, 2008; NSW, 2020). Table 4 shows the peak hour volume for different BRT systems around the world. Peak hour volume for most of the BRT system is in the range of 10,000 PPHPD. Peak per hour ridership is being observed for South-American BRT systems including Bogota, Sao Paulo, Curitiba that performed exceptionally well and even exceeded the ridership of many LRT systems. BRT in Brisbane, Australia provides a passenger capacity of 20,000. The majority of the BRT systems have peak hour volume in the range of 3,000 to 10,000 such as Leon, Lahore, Jakarta, and Ahmadabad.

Table 4 Peak hour volume for various BRT systems

City	Peak hour (passengers/ hour/direction)
Bogotá (TransMilenio)	45,000
Curitiba	20,000
São Paulo (Interligado)	34,900
León	2,900
Beijing	8,000
Hangzhou	6,600
Jakarta (TransJakarta)	3,600
Brisbane	19,900
Pittsburgh (MLK East Busway)	5,000
Istanbul	30,000
Ottawa	10,500
Guangzhou	25,000
Ahmedabad	3,000
Lahore	10,000
Ottawa West Transitway	10,000
Quito	11,700
Cleveland HealthLine BRT	15,800
Xiamen	8,360

Source: (BRTdata.org, 2020; Hensher, 2007; Reilly & Levinson, 2011; Wright & Hook, 2007)

TransMilenio has achieved overwhelming success in attracting a larger volume of passengers. During peak hours of the day, the system operates beyond its capacity. The large volume of passengers in TransMilenio is catered systematically through designed elements; four lanes are introduced (see Figure 13) at station to allow overtaking and bypassing of buses. The higher volume also results in lower TransMilenio reliability and comfort (Reilly & Levinson, 2011).

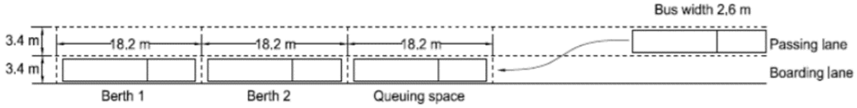


Figure 13 TransMilenio bus station plan view – *Source: (Reilly & Levinson, 2011)*

APPREHENDING BUS RAPID TRANSIT SYSTEMS

2.5.3 Capital Cost vs Capacity

The comparison between capital cost and capacity offered indicates that BRT provides capacity higher than that of LRT and at a much lower cost as shown in Figure 14. The capital cost (US$ million) is presented on the vertical axis and the horizontal axis shows the capacity (passenger per hour per direction). It indicates that BRT systems can also be preferred for a bit higher capacity than LRT and approaching capacities as that of elevated rail and underground metro at a much lower cost. In both conditions, the BRT system outweighs the LRT systems. However, it is not possible to achieve such a capacity with BRT-lite and where full-BRT provides such a high capacity there remains a question of reliability as observed in the case of Transmileno, Bogota. A similar relationship between capital cost and capacity is presented in Figure 15. In the figure, the x-axis represents the capital cost and the y-axis represents the capacity offered by different transport modes.

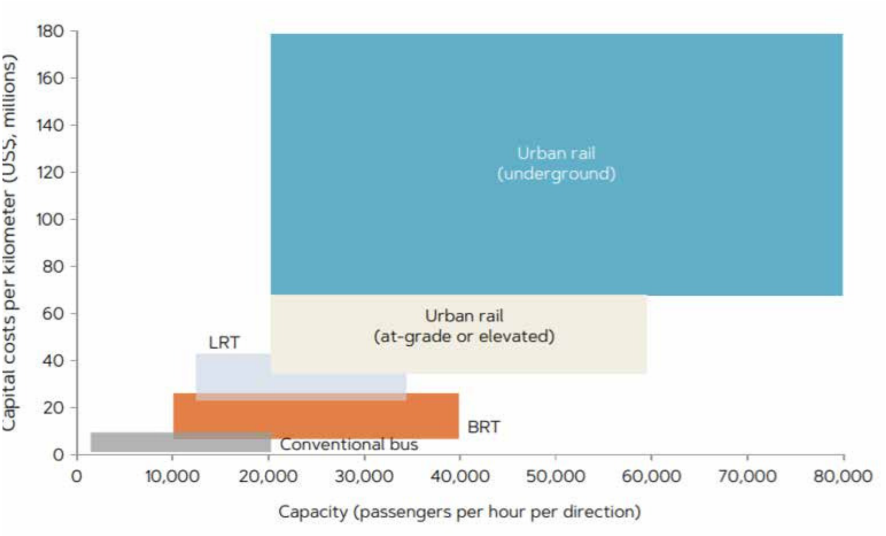


Figure 14 Comparison of Capital cost and Capacity

Source: (Pulido, Darido, Munoz-Raskin, & Moody, 2018)

For BRT the ratio of capital cost (USD/km) to capacity (thousand persons per hour per direction) is in the range of 200-250 whereas for the LRT system the ratio is in the range of 800-1000 which shows that the BRT system can offer higher capacity at a much lower cost compared to LRT.

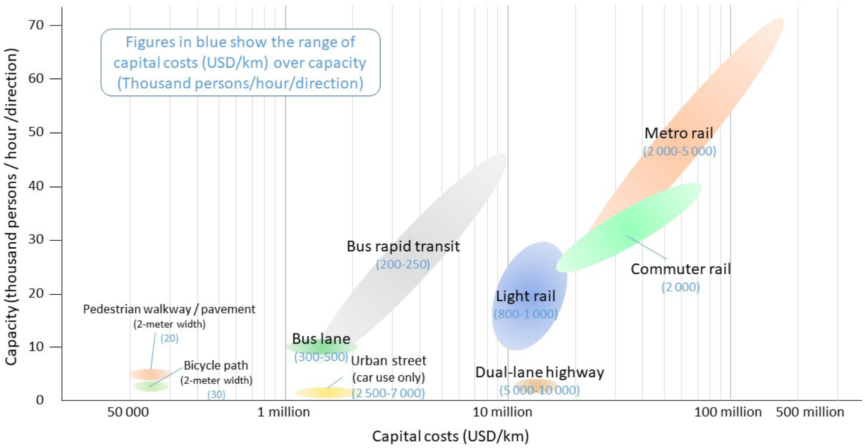


Figure 15 Relationship between Capital Cost and Capacity – *Source: (IEA, 2020)*

2.5.4 Ridership

Transit ridership is attributed to different tangible and intangible service features such as service frequency, reliability, comfort, and safety (Cain & Flynn, 2013). BRT system has greater ridership than regular bus operations. Over the last two decades, Curitiba's BRT system ridership has increased by 2.36% a year. In the U.S. BRT programs facilitated in increasing ridership from 27% to 100% (Matsumoto, 2005). However, the experience from Los Angeles has shown that LRT (Gold line) and BRT (Orange line) carry an equal passenger load (Flynn et al., 2011). Researchers suggest that normally ridership is higher for LRT than for BRT (Currie & Delbosc, 2013; Stutsman, 2002) as experienced in the case of Blueline (LRT). The latter outperformed the BRT-Harbor Transit-way by transporting four times more riders (LACMTA, 2005). This higher ridership may be attributed to the fact that LRT has a stronger image; since LRT has more permanent infrastructure than BRT. However, this claim is not true for a full-BRT system. A full-BRT system has similar image quality as that of LRT (Flynn et al., 2011).

2.5.5 Infrastructure

Infrastructure governs the efficiency of a system. The infrastructure of a transit service includes busways/running ways, vehicles, fare collection system, stations, and operational control system.

2.5.5.1 Running Ways

Running way is one of the basic elements of any transit system. BRT running ways can vary from mixed to fully segregated busways. Broadly, BRT running ways fall under three categories: on-street, on-freeway, and off-street (H. Xu & Zheng, 2011). BRT system operating with ROW-B and having other characteristics of BRT is known as BRT-lite (as discussed in section 2.4). These BRT-lite systems are operational in Boston (U.S.), Hong Kong, London, and Los Angeles. Such systems are implemented where constraints of land use and cost hinder the implementation of fully segregated running ways. However, the unavailability of a separate ROW can influence the reliability and speed, which is not consistent with the objective of BRT. Wright and Hook (2007) claim that BRT provides fast, reliable, and high-quality public transport service. BRT operation on separate running ways helps to improve the efficiency of the system. However, the provision of a separate right of way increases the capital cost of BRT (Wirasinghe et al., 2013). A typical BRT lane requires a width of almost 3.5-meters and a busway having a single lane in each direction requires a road width of 10-13 meters (Wright & Hook, 2007). Likewise, LRT can operate with mixed traffic as well as on a fully segregated and sophisticated elevated right of way, on the other hand, provision of guided way/ rolling stock is the basic requirement for LRT. In most LRT cases, standard 2.65-meter wide vehicles are used which has widely been implemented in Europe (Van der Bijl et al., 2018). A concrete base is used to dampen vibration and sound effects (Rode, 1999). A two-way track of LRT requires a horizontal clearance ranges from 8.5 meters (extremely narrow) to 15 meters (Clark, 1984). Besides rolling stock LRT also requires an overhead electric wire system that powered the whole LRT system. Provision of rolling stock and overhead wire system enhance the infrastructure cost of LRT systems, which is not required in the case of BRT systems. The latest LRT systems installed during the last few years (Including France, UAE, Qatar, Brazil) are also using modern wireless, semi-wireless, or battery technologies. These technologies include APS (Alimentation par Sol), PRIMOVE, ACR (Acumulador de Carga Ráàpida / Quick Charge Accumulator), Sitras HES (Hybrid Energy Storage), Catfree, and SRS (Système de Recharge statique par le sol in English static-based ground charging system). This shows that the LRT system requires intensive infrastructure development. Requirement of specific infrastructure for LRT makes its movement more restricted. In case of BRT, enhanced flexibility in vehicle maneuvering can be observed.

2.5.5.2 Vehicles

Vehicle length may vary in the case of BRT and LRT depending on the level of ridership. The type of buses available can differ from conventional to full-sized articulated and bi-articulated vehicles. Table 5 shows the vehicle length and capacity for different types of BRT buses. LRT vehicle features and appearance may differ from system to system depending on the operation. Light rail vehicle typically has a length between 24-34 meters (Van der Bijl et al., 2018; Rode, 1999; VTA, 2007), and width between 2.4-2.7 meters in the US (Rode, 1999) while, a width of 2.65 meters is mostly evident in case of Europe (Van der Bijl et al., 2018). Theoretically, the modern LRT vehicles have a high capacity providing a carrying capacity of 220-250 passengers per 35-meters long vehicle (Gunnarsson & Löfgren, 2001).

Table 5 BRT vehicle types

Vehicle type	Vehicle length (meters)	Capacity (passengers per vehicle)
Standard	12	60-80
Articulated	18.5	120-170
Bi-articulated	24	240-270

Source: (Wright & Hook, 2007)

LRT capacity and functional length increase when two or three vehicles are coupled however, the maximum length of the train is mostly restricted to 75 meters due to street operation (Van der Bijl et al., 2018). When three vehicles are coupled in a train, LRT can provide a capacity of around 630 passengers per train (ITDP, 2018). On the contrary, for BRT a separate driver and vehicle is required. The LRT system of Ankara, Bursa, and Adana in Turkey with triple trains are providing passenger capacity in the range of 300 to 350 persons (Vitosoglu, Ozden, Yaliniz, & Bilgic, 2014). The new low-floor operation of the Sneltram in Utrecht will operate in coupled set having a length of 75 meters and will provide a passenger capacity of almost 280 per vehicle (Zasiadko, 2019). The light rail in Odense, Denmark would operate with a 32-meter long modern tram with a passenger capacity of 200 passengers/single train (ObenseLetbane, 2020). Table 6 illustrates the length and maximum capacity for different LRT systems. It can be observed that vehicle passenger capacity is in the range of 212-450 which is greater than BRT systems.

Table 6 LRT vehicle length and capacity

City	Length (meter)	Capacity (passengers)
Lugano, Switzerland	45.42	298
Santos, Brazil	43.70	408
Sydney, Australia	67	450
Bybanen, Bergen, Norway	32.37-42.14	212-280
Budapest	53	150-350

Source: (Letbaner.DK, 2020; NSW, 2020; Stadlerrail, 2020)

Multiple doors are used for both systems, which support the quick boarding of passengers and result in better distribution of individuals within the vehicle. BRT vehicles may be powered by diesel or with more recent alternative fuels such as hydrogen fuel cells, CNG (compressed natural gas), LPG (liquefied natural gas), or electric power (Vuchic et al., 2012; Wirasinghe et al., 2013). On the other hand, LRT vehicles are mostly powered by electricity; new LRT technologies are also using batteries which make them a more environment-friendly mode of transport. Fully automated (driverless) LRT systems are operational in many cities like Putra LRT in Kuala Lumpur, Malaysia, and SkyTrain in Vancouver, Canada (CUTA, 2006; Mohamad, 2003). When vehicle life span is concerned, BRT vehicles have less life than LRT (Lopez Lambas & Giuffrida, 2017).

2.5.5.3 Stations

The success of transit systems mainly depends on the spacing, location, and design of stations as these provide a link between transit system and their customers. Physical design of the transit station includes the width and length of the platform, shelters, ticket machines, and information signs (VTA, 2007). Stations offer travelers with permanence and a sense of place. Although the location and placement of a station is a critical issue, a transit station must be well integrated with its surrounding areas, easily accessed, well designed, safe, comfortable, and attractive. Ticket machines, route maps, and real-time passenger information systems enhance the usefulness and functionality of the station (Transit, 2007). The width of a transit station is primarily a function of the projected peak volume of passengers (Wright & Hook, 2007). The ideal spacing endorsed by BRT standard 2013 is 1.5 km, beyond this spacing walk time increases gradually whereas, in the case of station spacing less than 1.5 km, bus speed is compromised (ITDP, 2013). In the U.S. and Australian cities station spacing of 1.5km is evident (Hensher & Golob, 2008).

According to Velásquez et al. (2007), station spacing of 300 to 800 meters results in the rapid operation of the BRT system. In densely urban areas, BRT stations are spaced 500 meters to 600 meters apart. In the case of LRT, it is recommended that stations may be placed every 0.4 km to 2 km (Van der Bijl et al., 2018). The design of the LRT station mainly depends on the characteristics of a light rail vehicle (e.g. high level or lower level vehicles). In both cases i.e. BRT or LRT; stations may vary from the very high-quality bus station with controlled transit centers to simple stops with shelter along with lighting and seating arrangements as shown in Figure 16 and Figure 17.

Figure 16 (a) Simple BRT station with Shelter facility (b) High-Quality BRT Station

Source: (Abbas, 2018; Bajwa, 2016)

Figure 17 (a) Simple LRT station with Shelter facility (b) High-Quality LRT Station

Source: (Hansen, 2019; Wikipedia, 2019)

2.5.5.4 Fare collection Systems

The fare collection system is a basic element affecting ridership, costs, and boarding time. Numerous alternative methods are used for fare collection including off-board, on-board, passes, or smart cards (Wirasinghe et al., 2013). In transit systems such as BRT and LRT, off-board fare collection is encouraged to reduce the overall travel time and enhance reliability. Off-board fare collection system permits passenger boarding through multiple-doors.

2.5.5.5 Operational Control Systems

Application of intelligent transportation system (ITS) technologies helps to improve BRT operation. These ITS technologies include specialized bus signals, automatic vehicle location (AVL), transit signal priority, and signal activation sensors (Wright, 2002). Most of the modern transit services such as BRT, LRT, Metro, etc. use ITS technologies to improve their services (i.e. high speed, improve reliability, etc.). On the other hand, ITS services also enhance user experience through the provision of user-friendly services and up-to-date information (i.e. time table, waiting time, etc.). Innovative technological applications can be implied in five different components i.e. guideways and stations, vehicles, fare systems, control systems, and passenger information systems. ITS technologies use may diverge reliant on the type of service, physical constraints, operating environment, and budget constraints (Diaz & Schneck, 2000). Transit signal prioritization provides priority or preference to the transit at a traffic intersection to minimize the delay. Vehicle prioritization is used by both BRT and LRT systems where needed. Passenger information technology helps to improve the travel experience of passengers. Vehicle schedule/information can be disseminated through stations, on the vehicle, or through cell phones. This technology is used by all sophisticated BRT (e.g. Los Angeles, Pittsburgh) and LRT (e.g. Calgary) systems at the same time passenger information help to reduce waiting time for passengers and enhances passenger satisfaction (Kattan & Bai, 2018; Kulyk & Hardy, 2003). Some new transit systems are also providing on-board Wi-Fi facility (Kulkarni, Kumar, & Kalaga, 2015).

2.5.6 Service Attributes

2.5.6.1 Speed

Increased travel speed is one of the overwhelming reasons for the customer to choose transit as their mode of travel. The speed of transit service is also influenced by stop spacing. A study in 11 Latin American cities by Hidalgo and Graftieaux (2008), indicates that travel speed is increased by 15-26kph, as regular bus operation is substituted by BRT service. Theoretically, LRT speed may vary from 15 km/h in pedestrian areas, 40 km/h in common urban areas to 100 km/h (maximum speed) in suburban areas; whereas, BRT system has a maximum speed of 70 km/h (Van der Bijl et al., 2018; Vuchic, 2005). The average commercial speeds of different BRT and LRT systems are presented in Figure 18. It is clear that there is no major difference between the average operating speed of BRT and LRT systems in different cities. In urban traffic conditions average operating speed of LRT and BRT is competitive with automobiles' average speed (e.g. 23-25mph).

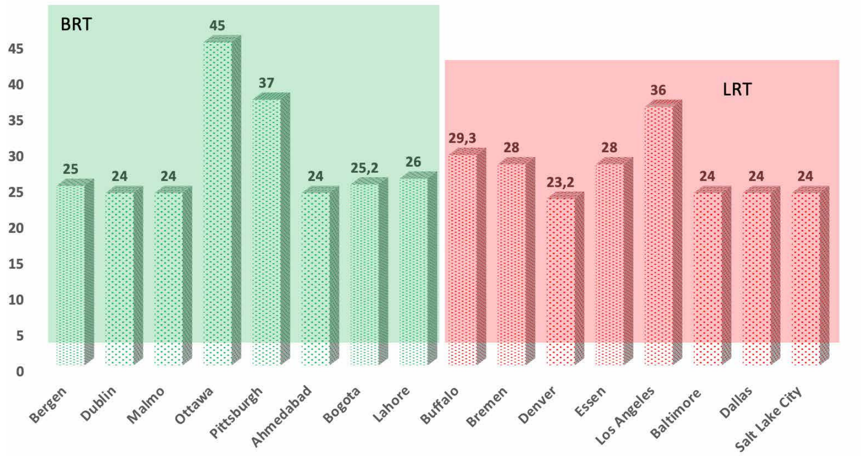


Figure 18 Average commercial speed on BRT and LRT line (km/hr) – *Source: (BRTdata.org, 2020; Carmen Hass-Klau, Crampton, Biereth, & Deutsch, 2004; TAPT, 2001)*

2.5.6.2 Headway

A minimum headway implies the least waiting time at the station, hence improving the passenger's experience. Typically a service operating headway of fewer than 10 minutes is considered as a high-frequency service (Delgado, Munoz, & Giesen, 2012; Ding, Chien, & Zayas, 2000; Flynn et al., 2011). Usually, LRT systems have greater headway as compared to BRT systems. LRT systems in Bursa, Turkey, Loss Angeles (Blue line), and South Pasadena, California (God line) operate with a peak headway of 10, 5-7, and 10 minutes respectively (Cain & Flynn, 2013; Rizelioğlu & Arslan, 2020). Most of the BRT systems (with a dedicated lane) operate with a peak hour headway of 5 minutes or less. In Jinan, China BRT is running with a headway of 3-4.5 minutes (Reilly & Levinson, 2011). Nevertheless, during peak hours headway for few BRT systems like Curitiba and Bogota is 90 seconds (Cervero, 2013a) which is far less than compared to most successful LRT systems. A headway of 13 seconds was also witnessed at some intersections of TransMilenio (Cervero, 2013a). Table 7 shows the average peak and off-peak headway for various BRT and LRT systems. It can be seen that for most of the BRT systems peak hour headway is in the range of 2 minutes, whereas for the LRT systems peak hour headway is in the range of 10 minutes. Yet, few LRT systems run with a headway of 5 minutes or less. Besides frequency, service reliability is an important aspect for impelling mode choice. Facts about reliability and deviation in tabular form have been discussed in the next section for both BRT and LRT systems.

Table 7 Average peak and off-peak headway for BRT and LRT systems

City	System	Average peak headway	Average off-peak headway
Goiânia	BRT	40 seconds	2 min
São Paulo	BRT	30 seconds	45 seconds
Quito	BRT	2 min	5 min
León	BRT	2.5 min	7 min
Beijing	BRT	1 min	4-8 min
Hangzhou	BRT	2 min	5 min
Seoul	BRT	12-15 seconds	15-20 seconds
Adelaide	BRT	50 seconds	5–15 min
Amsterdam	BRT	7.5 min	10 min
Ottawa	BRT	2 min	15 min
The Tide light rail	LRT	10 min	15-30 min
Newark Light Rail	LRT	10 min	15 min
Baltimore Light Rail	LRT	20 min	30 min
VTA Light Rail	LRT	10 min	15-30 min
MAX Light Rail	LRT	15 min	15-20 min
Los Angeles Metro Rail	LRT	5-10 min	10-15 min
Calgary light rail	LRT	3-5 min	6-10 min
Bergen Light Rail	LRT	4-5 min	8 min

Source: (HRT, 2020; Metro, 2020; MTA, 2020; NJTransit, 2020; Sirisoma, Wirasinghe, & Morgan, 2010; Skyss, 2020; Trimet, 2020; Wikipedia, 2020; Wright & Hook, 2007)

2.5.6.3 Reliability

Reliability is generally defined by the confidence level one devises in the public transport's ability to perform as expected (Wright & Hook, 2007). Reliability has emerged as an important attribute of public transport which determines the quality of a transit facility. It is an aspect that is equally significant for both carriers as well as for travelers (Kathuria, Parida, & Sekhar, 2019). Reliability is a basic element of the customer requirements pyramid. Research has shown that reliability significantly influences the choice of route and mode (Abdel-Aty, Kitamura, & Jovanis, 1995; Van der Bijl, 2018; Lam & Small, 2001), as travelers are more likely to choose a transit that is considerably reliable (Wirasinghe et al., 2013). There are three major effects of unreliability including deviation in arrival time, increase in travel time, and crowded vehicles. The discrepancies in headway and travel time prolong the waiting time at stations and thus influence the reliability and total travel time for passengers (Van der Bijl, 2018). A BRT system with separated right of way have advantage of better headways and frequency hence improving reliability for passengers (Wright & Hook, 2007). The study by Flynn et al. (2011), indicated that a full-BRT facility can duplicate both the image quality (intangible) and functionality aspects (tangible) usually associated with LRT. The comparative flexibility of BRT systems to function inside/outside of the separated infrastructure permits immediate modifications to any emergency/breakdown. Whereas, in the case of LRT additional time is required for remedial actions and clearance of immobilized vehicle from the system (Wright & Hook, 2007). A review of the Orange line (BRT) reveals that 82% of the customers are satisfied with the service reliability. The orange line meets its timetable with an average deviation of 32 seconds only. The investigation of BRT (Dar es Salaam) in Tanzania, divulges that staff and passengers are satisfied with service reliability (Kiwelu, 2017). Satisfaction level for TransMilenio in Bogota has declined steadily from 4.60 in 2001 to 2.62 in 2016 (on a 5 point scale) (Garcia-Suarez, Rivera-Perez, & Rodriguez-Valencia, 2018). Fjellstrom (2014), indicated improvement in customer's perception of reliability after the opening of BRT in Changzhou. Contrary, Huo, Zhao, Li, and Hu (2014) observed the worst service reliability during morning and evening peak hours for the BRT system in Changzhou. High travel time variability was observed during peak hours for BRT in Ahmedabad (Kathuria et al., 2019). Variability in travel time also influences the dwell time. The study for LRT systems in various cities of France (including Rouen, Nantes, Saint Etienne and Le Havre) showed that total dwelling time is 25-30% of the vehicle's entire journey time. Dwell time can negatively influence the perception of travelers (Ibarra-Rojas, Delgado, Giesen, & Muñoz, 2015). Similarly, waiting time is valued from 1.47 to 12 times as that of in-vehicle time or travel time (Abrantes & Wardman, 2011; Diab, Badami, & El-Geneidy, 2015; Wardman, 2001). The analysis of LRT in Calrgary, Canada reveals a satisfactory service reliability for inbound direction compared to outbound direction (Sirisoma et al., 2010). The Randstad-Rail system in Netherland is performing quite well with a maximum delay of more than 2 min for 5% of all journeys and a delay of 4 min for only 1% of all trips (Van der Bijl, 2018). LRT in Hong Kong is operating with a punctuality of 99.9% (ITDP, 2016b).

2.6 Summary

Diverse transportation modes have emerged from time to time to cater to the ever-increasing demand for mobility with an increase in the world population. BRT is a new concept of urban mobility that has emerged as a cost-effective alternative. However, in the past few years, there remains a debate over service attributes attached to BRT. Different definitions are being used by researchers to define BRT, but each definition depicts varying service attributes of BRT. Moreover, there was also a need to define categories of BRT based on some common criteria. In this chapter, based on the past studies and service attributes; BRT is divided into two categories based on the right of way (ROW). BRT-lite is a type of BRT using ROW category B (partially separated ROW) whereas, Full BRT operates on ROW category A (Fully separated ROW on the majority of its corridor). This classification can better help to compare BRT with other transit modes like LRT. Both transit systems are often compared because this requires a huge amount of public resources whereas local governments have limited resources to invest in public transport. Moreover, it was important to establish a comparison between BRT and LRT because BRT is always defined in comparison to rail transit systems.

In this chapter a comparison between BRT and LRT is established based on capital/ operational cost, capacity, infrastructure (e.g. running ways, vehicles, station, fare collection system, operational control system), ridership and service attributes (e.g. speed, headway, reliability. The comparison between BRT and LRT reveals that

BRT requires much lower capital investment compared to LRT. Therefore, the BRT systems are mostly being developed in developing countries. The experience from the U.S. shows that BRT systems also entail lower operational costs such as the cost per revenue hour and cost per passenger. Likewise, waiting time cost, access time cost, and in-vehicle time costs are less because of the higher frequency of BRT. The analysis of capacity in passengers per hour per direction (PPHPD) indicates that LRT in Europe is performing relatively better, providing a capacity of 20,000 PPHPD. Most of the LRT system in the U.S approaches a capacity of 10,000 PPHPD. The LRT system in Sydney achieves a capacity in the range of 13,000 PPHPD. Analysis of the capacity for BRT systems divulges that few Latin American systems like in Curitiba, Bogota, and Sao Paulo performed exceptionally well, providing a capacity greater than many LRT systems. However, additional infrastructure is required at stations which could enhance the capital cost. Moreover, for BRT systems with high capacity like Transmileno, there remains a question of reliability. The analysis of capacity for the BRT system indicated that most of the systems worldwide have the capacity in the range of 10,000 PPHPD. BRT systems having an exclusive right of way can achieve higher capacities and can achieve the capacity that of an LRT. However, to achieve the capacity of an LRT, the BRT system needs to operate with a higher frequency. For example, the Orange line (BRT) and the Gold line (LRT) in Los Angeles provide similar capacity but the Orange line operates with a headway of 5 minutes whereas the Gold line operates with a headway of 15 minutes.

Concerning the running ways, both LRT and BRT systems can have the infrastructure to operate with mixed traffic or on exclusive lanes (varies across different systems). A wider right of way is required for BRT which is the major cost associated with BRT development. However, for an LRT system infrastructure such as rolling stock, electric infrastructure and concrete bases are the basic requirements which are also one of the reasons for the higher cost of the LRT system. Different types of vehicles are used for BRT and LRT and in both cases, vehicles can be altered (articulated and bi-articulated/ coupled). The vehicle capacity is greater for LRT systems. Theoretically, an LRT system operating with 4 trains can offer a vehicle capacity of approximately 630 passengers per train. It is evident from experience that the vehicle capacity of different LRT systems ranges from 212 to 450 operating around the world. In the case of BRT, the maximum bi-articulated vehicle can be used that provides a vehicle capacity of 280 passengers which is less than LRT. It implies that with this vehicle capacity a BRT system has to be more frequent (less headway) to match the passenger capacity of LRT and this is apparent from the experience as most of the BRT systems operates with an average headway of 1-2 minutes whereas LRT system operates with an average headway of 5 minutes. The least headway implies that there would be the least waiting time for passengers. It also implies that there are fewer chances of further service improvement. Both types of transit systems (BRT and LRT) use intelligent transportation system technologies (ITS) for fare collection, automatic vehicle location, and passenger information. However, the use of ITS technologies varies across systems. In terms of ridership, LRT encompasses BRT; having the ability to attract more riders and satisfy higher demands. Therefore, LRT might be a preferred alternative when there is high demand. In this way, higher ridership in the future can also be catered. The comparison between different operational BRT and LRT indicates that both transit systems have almost similar operating speeds. Reliability varies across different BRT and LRT systems. Generally, systems with an exclusive right of way have higher reliability as compared to systems operating with mixed traffic.

The overall analysis of both systems shows that BRT and LRT systems have almost similar service attributes and a BRT system can provide similar services as that of LRT at a much lower cost. However, every transit system is efficient when place in the right place for the right people. Moreover, BRT is an attractive and efficient mode of mobility for countries with limited public resources. Therefore, based on former definitions, categories, and its comparison with LRT following definition of BRT can be devised and will be used for this research.

Bus Rapid Transit (BRT) is a rubber-tired transit system that delivers fast, comfortable, reliable, flexible, cost-effective, and high-quality urban mobility through provision of partially/fully segregated right of way, regular or articulated buses, iconic stations with pre-boarding fare collection system and intelligent transportation systems elements to enhance user experience.

3

Space, System and their Interrelations towards a Theoretical Framework

Part of this chapter have been previously published as:
Basheer, M. (2020). Application of an actor relational approach in Bus Rapid Transit-land use interaction.
In OPENING UP THE PLANNING LANDSCAPE (pp. 215-223). In Planning

3.1 Introduction

In the previous chapter, we have delineated a definition and various characteristics of Bus Rapid Transit (BRT) along with its expansion around the world. Besides transport, there are also other benefits (urban development and economic) that may arise from transport investment. However, externalities associated with transport investments are difficult to predict and may vary in specific geographical contexts. Therefore, firstly the motives and processes linked to BRT investment and specific characteristics coupled with its impacts must be explored. An appropriate approach could help to identify the interrelated phenomenon that leads to change in travel behavior, urban development, and economic development. All these components are interrelated and influence each other, more often in an unpredictable way. Before going into details of the interrelation between BRT investment and its impacts we first need to understand what space is (from a geographer's point of view) in which these systems exist and how different systems work in our society. Structuralist and post-structuralist theories can help to understand the concept of space and how these spaces develop? At the end of this chapter, an Actor Relational Approach (ARA) is identified which helps to understand the interrelation between different systems in our space.

3.2 Land-use and Transport Interaction

The land-use and transport interaction refer to the process of coordinated urban development that encourages the choice of sustainable transport modes such as walking, bicycling, and public transport. The objective of land-use and transport interaction is to create a balance between transport and land-use needs. Mitchell and Rapkin (1954), are often considered as the pioneer for articulating the interaction between transport and land use in their book Urban Traffic: A Function of Land Use (Handy, 2005). Since then the theoretical basis to study this interaction has evolved appreciably. There is a growing consensus among researchers that transportation policies alone cannot promote sustainable development and these should be complemented by public assistance and appropriate policies (Handy, 2005; Suzuki et al., 2013; Wegener, 1995; Wegener & Fürst, 2004). In the past, researchers have tried to highlight the mechanism behind transport-land use interaction as shown in Figure 19 and Figure 20. Figure 19 implies that in an urban setting, the association between transport investment and land development is linear where investment in transport triggers urban development: new commercial activities. These new development activities ultimately generate new travel patterns.

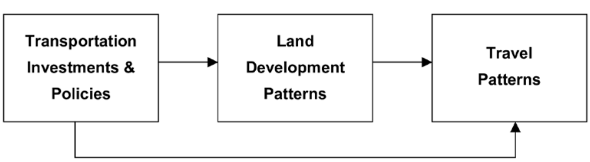


Figure 19 Basic Link between Transport and Land use – *Source: (Handy, 2005)*

According to Giuliano (2004), the association between transport and land use is a continuous process. Investment in transport in an urban setting improves accessibility, which is then capitalized through the urban development benefits that ultimately alter the travel patterns of individuals. These travel patterns further generate the demand for new transport services or enhancement of existing transport services and this cycle continues.

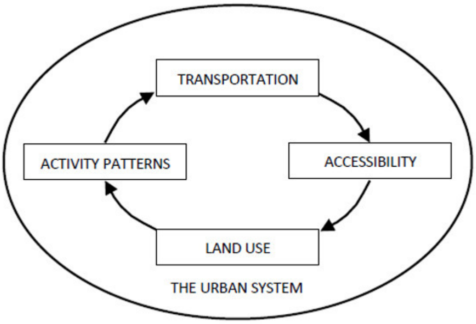


Figure 20 Transport Land-use Connection – *Source: (Giuliano, 2004) by (Higgins, Ferguson, & Kanaroglou, 2014)*

Higgins et al. (2014), identified six factors that influence land development resulting from rapid transit service. These factors include transit accessibility, positive growth and demand, positive social conditions, positive physical conditions, land availability, and complementary planning. The land-use model developed by B. Still, May, and Bristow (1999) also explains the interrelation between transport investment and the process of urban development (see Figure 21). The model also incorporates economic development (employment), locational choice, demographics, and changes in the quality of the urban area. Moreover, sub-models are calibrated for each component of a land-use model. These models are developed for any type of transport investment; but nature of interrelation between urban development and economic development still needs to be explored in the case of BRT.

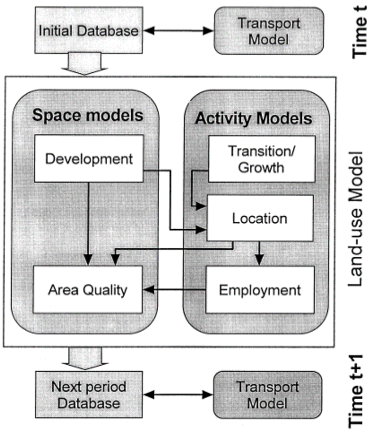


Figure 21 DELTA Land use Model Structure – *Source: (B. Still et al., 1999)*

Instead of the simple linear relationship, the relationship between transportation, travel pattern, and land development is of endogenous nature as countless exogenous factors influence these interrelations. The factors related to travel patterns may include sociodemographic characteristics and attitudes. Factors related to transport investment and urban development may include political forces and land use policies (Handy, 2005). Therewith we cannot investigate for instance BRT systems without taking into consideration also these elements in interaction. Moreover, these interrelations are not simple as they seem to be; rather these interrelations are more complex as there are a number of actors and factors involved in this process as shown in Figure 22.

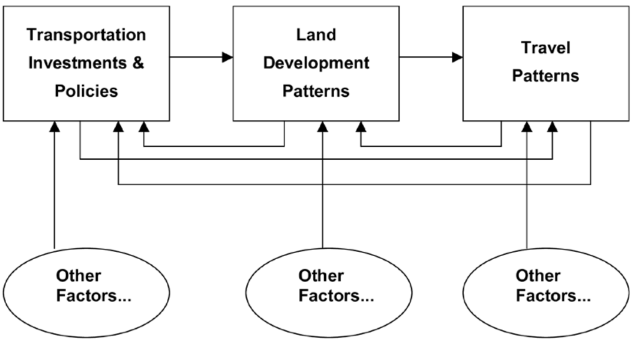


Figure 22 Complex links between Transportation and Land Use – *Source: (Handy, 2005)*

The complex link presented here does not reflect upon the intermediate process which triggers land/urban development after investment/improvement in transport. Moreover, they does not provide us with a broader picture of interaction between transport and land use. The involvement of different people/agencies, their choices about an investment makes this link between transport and urban development complex. These land use and transport interaction models do not express anything about the conditions or factors which are prerequisite for any land value or land-use change (Cervero, 1984; Knight & Trygg, 1977; Vessali, 1996).

Moreover, actors and institutions have an important role to play in transport-land use interaction. The poor coordination between different actors (actors related to transport and land use) often results in negative spillovers and inefficiencies. In reality, decision-making is distributed among many actors and jurisdictions. Therefore, considering these complexities a more sophisticated and complex-sensitive research design and approach is required. Whereas for all these propositions questions remain about the transport and land use interaction and direction of the causality. Thus, we have combined these transport-land use research with actor relational approach for a better understanding of interaction between transport and land use. According to Luhmann (1997), to deal with this complexity it is appropriate to approach the complex and volatile reality through distinct and autonomous subsystems (Boelens, 2018, 2020). For this purpose, it is necessary to study the constitution of space and how these systems (transportation, urban development, and economy) work in space. Therefore, it brings us to structuralist and Post-structuralist theories that outlines the constitution of space, systems, and sub-systems.

3.3 Structuralist and Post-structuralist Theories

The structuralist theory sees space as something as abstract and zoned (Murdoch, 2005). Space is just like a surface constituted by various underlying structures. Structuralism is an intellectual movement developed from the work of Ferdinand de Saussure. For structuralists unpredictable and chaotic character of social life is something illusion and beneath this level, there exists an organized, order and pattern which is made up of a limited number of elements. In each system, these elements combine to stimulate action and these systems are inevitably closed. Thus, the investigation of society should focus on the underlying mechanisms instead of social actions (Murdoch, 2005; Smith, 2001). Levi-Strauss in his article "History and Anthropology" states that

> *"If, as we believe to be the case, the unconscious activity of the mind consists in imposing forms upon content, and if these forms are fundamentally the same for all minds ---- ancient and modern, primitive and civilized… it is necessary and sufficient to grasp the unconscious structure underlying each institution and each custom, in order to obtain a principle of interpretation valid for other institutions and customs, provided of course that the analysis is carried far enough" (Levi-Strauss, 1963)*

Herewith Levi-Strauss provides the way to study and interpret various social systems in our society. According to him if we can analyze the unconscious activities of the mind then we can interpret the underlying structure of each custom and institute and this is not the case in reality particularly while studying different social systems. As unconscious behavior of a person is constituted through an interrelation within society (Matusky, 1986). Similarly, while studying the impacts of BRT it is important to evaluate the impacts through their interrelation because these impacts are closely interrelated and context-dependent (changes in different geographical situations). For example, change in economic conditions can influence urban development and travel behavior of people which may or may not only be subjected to transit investment. This brings us to post-structuralism, according to which space cannot be seen as a "container" of different heterogeneous processes/elements. Rather, space is something that is stabilized out from chaotic processes (e.g. heterogeneous relations) (Murdoch 2006).
Accordingly, the post-structuralist theory claims that systems are dynamic, open, and fluid; therefore something other than a formal analysis is needed. The post-structuralists do not believe that any system can be studied through its underlying structure; that is, according to De Roo (2010), social categories are never normalized, stabilized, or structured. There exist different kinds of relations in a given location, and actions must be investigated in the context of wider relationships. Therefore, post-structuralism primarily focuses on heterogeneous relations; social and natural, human and non-human. Systems around us and to which we belong are continuously in the process of becoming. So, two different concepts of space and system emerge; one (structuralist) perceive space as systematic, which can be studied by focusing on these systems, and these systems are closed in their nature, while the other (post-structuralist) emphasis space as something that is stabilized from heterogeneous relations

and it is important to study these heterogeneous relations to understand any system in the state of becoming. Hence, relationality has important implications for the investigation of place and space. Harvey and Braun (1996) perceive the idea from post-structuralism that space is not like a container; rather space is something that depends on processes that make it up. From Whitehead they drive the idea that these processes are established from relations. Similarly, (Massey, 1992, 1998, 1999, 2005) tried to explore the relational space. Massey (1998), proposes a relational approach and outlined three fundamental propositions intrinsic to this approach. First, space emerges as a result of interrelation, and these relations run through various spatial scales. Thus, space is relational. Secondly, space is full of multiplicity. For Massey (1998), "without space, no multiplicity; without multiplicity, no space". Thirdly, space is never fixed nor closed and is always in a process of becoming. Therefore, planners need to focus on relational space and how a particular spatial configuration came into being. Since the early 20th century, new insights with respect to non-linearity, unpredictability, uncertainty, and disorder are also being recognized as fundamental. Lorenza indicated how minor variations in initial conditions could lead to radically divergent, and unpredictable outcomes. These uncertainties force us to include complexity and chaos as an integral part of our life (Gleick & Berry, 1987; Holland & Wolf, 1998; Kauffman, 1995; Waldrop & Gleick, 1992). It is also important here to indicated differences amongst complicated and complex systems. A clock is a perfect example of a complicated system that is sophisticated, consisting of different parts working all together as a single entity. In case of any damage, a clock specialist can repair any part of this and put the system again back into working condition. However, this is not possible in the case of a complex system as every part has an influence on other parts and it is difficult to put complex systems back into their initial setting in case of any breakdown. In short, elements before structure or structure before elements (Boelens & de Roo, 2014). Subsequently, it is tough to predict complex systems (Bovaird, 2008). Nevertheless, structure develops out of this chaotic situation as indicated by Stacey.

> *Contrary to some of our most deep-seated beliefs, mess is the material from which life and creativity are build and it turns out that they are built, not according to some prior design, but through a process of spontaneous self-organization that produces emergent outcomes. (Stacey, 1996, p. 9)*

It shows that a system develops through different interrelated processes. In a system, there exist many interrelations, that even a process that is run several times will not provide the same result under similar conditions. It is also important to mention here the differential system theory presented by Luhmann. According to differential system theory, a society (system) is composed of different (sub) systems, such as political, economic, or legal systems (Boelens, 2020). The core element which constitutes society is communication thus relations. Communication or relations within a system can be considered a basis for the assessment of the operation of that system (Mattheis, 2012). Therefore, the situational approach gains more attention over the generic approach (De Roo, 2010), and in planning, the emphasis is shifted from the planning of predicted futures towards the planning of undefined becoming (Boelens & de Roo, 2014). Hence, it is necessary to know what constitutes a system of transport and urban development? And how these components interact for the working of these systems.

3.4 Actor-network Theory

Actor-network theory (ANT) is concerned with the creation and transformation of the heterogeneous network (J. Law, 1992). ANT acquires the knowledge about actors and how they (un)intentionally involve in dynamic networks that collectively (re)produce the system. The actor-network theory was conceptualized by Callon and Law based on four basic principles.

- Social phenomena are fundamentally heterogeneous
- All actors are networks of heterogeneous elements, which are unpredictable and are not fixed either in space, form, or time
- The identity of these actors/entities changes within their interaction in the network
- Every social arrangement is a point (individual) and network simultaneously and it depends on the level of zooming in or out; it's only a matter of perspective.

The theory is based on actors and their relations, e.g. networks. These relations not only co-exist between actors themselves but also with other actors and non-human actors. Therefore, before going into more detail it is appropriate here to understand the concept of actors and actor-networks. As such ANT treats people and objects in a similar way (e.g. human and non-human are similar in the way they both constitute heterogeneous networks). ANT was developed to examine situations in which it is hard to segregate human and non-human, and in which variable forms are associated with actors. According to Latour (1996), an actor can be anything whatsoever, provided that it is the source for some action. However, J. Law (1992), argues that effects generated by networks of heterogeneous elements can also be regarded as actors. In terms of actor-network, an actor is a simplified actor-network and at the same time, it can be part of other actor-networks. Actor-networks are formed through enrollment of human and non-human participants in a network that could be achieved through processes of translation (McLean & Hassard, 2004). It is the result of alignment between actors that they constitute an actor-network. The translation is a process of showing how the non-aligned interest of an actor could become aligned. Once a network is established these are not inevitably fixed or stable between different heterogeneous actors (J. Law, 1992). The actor-network theory assumes that actors involved are continuously organizing and reassembling their networks more vigorous and innovative (Boelens, 2010).

There also exist criticisms on actor-network theory (ANT) as it is criticized because of neglecting macro-scale social structure and only focuses on local contingencies (Naidoo, 2008). Moreover, treating all actors equally is problematic. All actors are not equal, as some actors exert more influence than others (Mutch, 2002). Likewise, from the current planning practice, Boelens identified three basic imperfections of actor-network theory in the field of spatial planning. In term of its analytical power-that is, how things come to their present state, ANT stands out. However, the first imperfection is mainly concerned with ANT limitation to give details for sustaining or improving certain initiatives. Therefore Boelens (2010), argues that actor-network theory stops where spatial planning begins. The second criticism by Boelens is similar to that of Mutch (2002) as all actors are not equally weighed in the network. Human actors are conscious and are capable of negotiating and anticipating which is different in the case of non-human actors. No doubt these non-human actors should be involved in the actor-network association. However, they tend to be represented through some mediated or intermediaries form (Boelens, 2010). Therefore, it is important to differentiate between (non-human) factors and (human) actors. Thirdly, the last phase of translation in ANT does not spotlight on how support is provided for actor-network associations, etc. (Callon, 1999). As planners/geographers, we need to plan for the future and one should take into account actors of future generations, which will ultimately become the important component of the network. This is important especially when talking about sustainability (Boelens, 2010).

3.5 Actor Relational Approach

Boelens (2010) presented a planning approach that begins from actor-network theory (ANT) but tries to mold it towards planning. The purpose of this approach is to respond to imperfections in ANT. The actor relational approach focuses on the outside-inward rather than the inside-outward approach. Boelens developed his idea form amongst other urban regime theories (URT) (Stoker & Mossberger, 1994; Stone, 1993) and associative democracy (AD) (Cohen & Rogers, 1992; Hirst, 1994), and lots of experiments in practice. Instead of focusing on the perspective of actors in ARA, the actor relational approach concentrates on the specific role of planners in actor networking processes. This approach does not particularly focus on a specific plan or formal institution as a given central objective. Rather this approach demands a prominent role for the neutral mediator or moderator and provides an open medium to explore and sketch the opportunities in a complex and uncertain world (Boelens, 2010). The example of one actor-network subsystem presented by Boelens (2018) is shown in Figure 23. The sub-system presented here is different from the system of actor-network theory as it differentiates between human and non-human actors. There are three major components of each sub-system as shown in Figure 23; (1) actors which mainly include human actors like public, business, and civic actors (2) Factors of importance including non-human actors such as infrastructure, land scape, water, buildings, environment or other geographical features and these are represented through mediators or intermediaries. Mediators are human experts which translate the desires/wants of non-human actors and intermediators include devices such as computers or television which are also source to represent non-human actors (3) Institutions can be formal or informal and they present the rules and regulations that are prevalent in a given subsystem. In the actor-network approach, institutions refer to legislations, rules, and regulations.

The interrelation between different actors in specific dynamic settings affects the conscious actors and locatable dynamic setting which further drives change. Therefore, agencies and institutions co-evolve in a positive, as well as a negative way. Agencies and institutions are never closed but are continuously in a state of becoming and thus always in a condition of innovation. In case of exceptional situations, institutions innovate themselves or strict to their behavior or perspectives. Therefore, any change in surroundings could strengthen or expand institutions to achieve better fitness with its surroundings. Institution framed by the action while actors are free to choose their specific path in the specific situation.

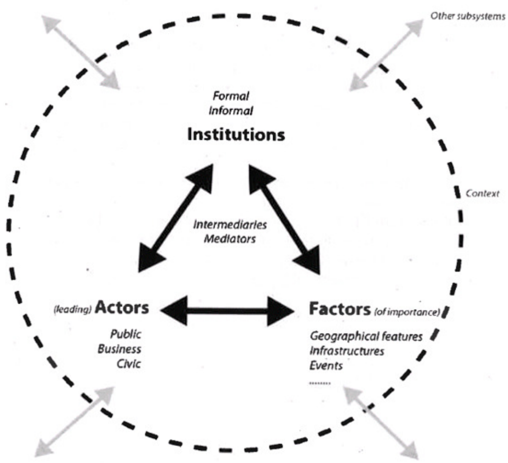


Figure 23 Actor Network Constellation – *Source: Boelens, 2018*

For Jessop (2001), reflexivity would reconstitute institution and their resultant framing. Institutions then would have a specific power, but they could redefine the power geometries through different ways of institutionalizing and organizing social interaction. Moreover, institutions would be certainly spatiotemporal, which arise in specific places at a specific time, to function in one or more specific actor relational spaces and in particular temporal horizons.

Institutions could modify themselves over time based on actant-relational needs. This innovation hardly arises from within but is irritate from outside-in by altering factors of importance or conscious actors in the environment, mainly operating from a different subsystem. Through this process, institutions could enlarge, expand or renew and would have an impact on the actors involved and factors of importance. Institutions in every subsystem could irritate other subsystems that would need to innovate themselves to survive. Hence, actors, factors, and institutions (re)constitute each other in a specific spatio-temporal setting. This phenomenon of innovation has great implications in the case of transport investment, as inducing any change/innovation in transportation (sub)system would affect the other (sub)systems such as the economy and urban development. It is because these subsystems are highly interrelated and any change in one subsystem would affect the working of other subsystems.

Innovation or change in any of these disturb the environment for other subsystems and other subsystems mold themselves to retain in stable condition. Innovation is referred to as the application of a new system or product to cater to the market demand (Maranville, 1992) as in the case of transport it can be viewed as the implementation of new Bus Rapid Transit (BRT) system. Economic theories mentioned innovation to be an endogenous force (Boelens, 2018) which can relate to the development of BRT because the increasing pattern of mobility and demand of transport provide means for the development of BRT and new transport need, emerged inside the system. Traditionally, institutions play their role to create stability in the ongoing change (Greenwood & Hinings, 1996) and they are also considered as a major restraint for any change (Boelens, 2018). Institutions always try to redefine themselves in a changing society. This change in society may occur because of actors, factors, or institutions themselves. This research will investigate the circumstances/conditions which triggers the development of BRT in Lahore and how different sub-systems (institutes, actors and factor) of society have been organized and interrelated before and after the implementation of BRT.

It is important to identify these impacts for the creation of sustainable neighborhood and transit-oriented development (TOD). A more complexity-sensitive approach like the actor relation approach can help to better understand different sub-systems and interrelation between them. ARA delineate the process of studying various systems and sub-systems first through the identification of component of a subsystem (including actor, institutions, and factors) and secondly by evaluating interrelation among several sub-systems.

3.6 Summary

In this chapter, different theoretical models defining interaction between transport and urban development have been discussed in detail. It seems that present models are more generic and do not sufficiently describe the interrelation between BRT investment and land use seeing the complexity of the situation. In all these transport and land-use interaction models a linear relation is described whereas the association between transport and land-use is more complex and relational. There is a need for a more complex sensitive approach to explore different actors involved, factors influencing each component, and their interrelations. Thus, the complex relationship between transport and urban development has been enlightened from the perspective of basic urban planning/geographical theories. According to Luhmann (1997), to deal with this complexity it is appropriate to approach the complex and volatile reality through distinct and autonomous subsystems. For this purpose, it is necessary to study how each system (transportation, urban development, economy, and travel behavior) works, which factors and actors are important and how these systems are governed. The actor-relational approach (ARA) can help to identify important factors in each system and their interrelation with other systems. In complex situations, the actor-relational approach not only provides a way forward where one can study different complex systems and the interrelations among them but also provide ways to improve the interrelation between various sub-systems. ARA delineates the process of studying various systems and sub-systems first through the identification of components of a sub-system (including actors, institutions, and factors) and secondly by evaluating interrelations among several sub-systems.

4

Key Defining Indicators for Urban Transition and Transport Investment

4.1 Introduction

It is clear from chapter 3 (theoretical framework) that innovation (i.e. implementation of BRT) in any local setting disturbs the equilibrium (change in travel pattern and hierarchy of institutions) in the society. In this situation institutions try to (re)constitute themselves to adapt to this transformation, and the interrelation between different subsystems also changes. Therefore, in this research travel behavior, urban development, and economy were considered as a sub-system that represents an overall transport-land use interaction system, and any change in their actors, factors, or institutions after the development of bus rapid transit was investigated. Moreover, the interrelation between these subsystems was explored.

To evaluate any change in the local setting due to the implementation of BRT it is important to first identify different impacts that BRT can bring. For this purpose, different thematic cores are defined in this research to evaluate the impacts of BRT. These correspond to BRT impacts on travel behavior, urban development, and economy. Travel behavior impacts imply modal shift, travel time, and travel cost-saving. Transition in the urban environment resulting from BRT implementation narrates to change in land use, redevelopment, fresh development, and variation in urban density. Economic benefits originating from BRT investment corresponds to variation in property values, inward investment, and extension of the labor market. Transport, urban development, and economic system were treated as separate subsystems. The actor-relational approach helps to identify the constitutional elements of these subsystems (actors, institutions, and factors) and subsequently helped in evaluating transition within these subsystems. These subsystems are closely interrelated and transition in one subsystem may also trigger a change in the other (R. D. Knowles, 2012). There might be various actors in each subsystem that are also part of another subsystem therefore it is important to explore the role of each actor and how these are linked to another subsystem. This can be investigated through the use of the actor-relational approach.

The first section spotlight on different impacts of transit investment using past literature particularly focusing on the impacts of bus rapid transit (BR). All the previous studies focus on the direct impacts of transit investment while ignoring the interrelation between the impacts of transit investment. According to Boelens (2020), in an urban setting, everything is relational thus the interrelation between these impacts should also be taken into account when studying the impacts of transit investment. In the next section, the primary components (e.g. actor, institutes, and factors) were identified for three subsystems using the actor-relational approach. Figure 24 shows the overall methodology for this research moving from the impact of bus rapid transit on different subsystems and interrelation between them using the actor-relational approach of planning. This research is unique in the way that it combines two different approaches to explore the interrelation between transport, urban development, economy. First, the impacts of BRT are investigated by calibrating different statistical models. Secondly, the actor-relational approach is used to explore the interrelation between these subsystems. To identify and analyze the changes in factors of importance different methods and statistical models including map analysis, binary logistic regression, performance analysis, geographically weighted regression were calibrated for these subsystems. These models help in exploring the impacts of BRT on travel patterns, urban development, and the economy. Besides the direct impacts of BRT; indirect impacts were also evaluated through interviews with different stakeholders. Indirect impacts correspond to the interrelation between BRT impacts (e.g. economy, urban development, and travel behavior). Extensive primary and secondary data collection was done for this study. Primary data collection includes field surveys (land-use surveys), questionnaire surveys, inquiries, and interviewees. Whereas, secondary data mainly include transport plans, urban development plans, building and zoning regulations, land-use maps, Punjab development statistics, district collector rate lists.

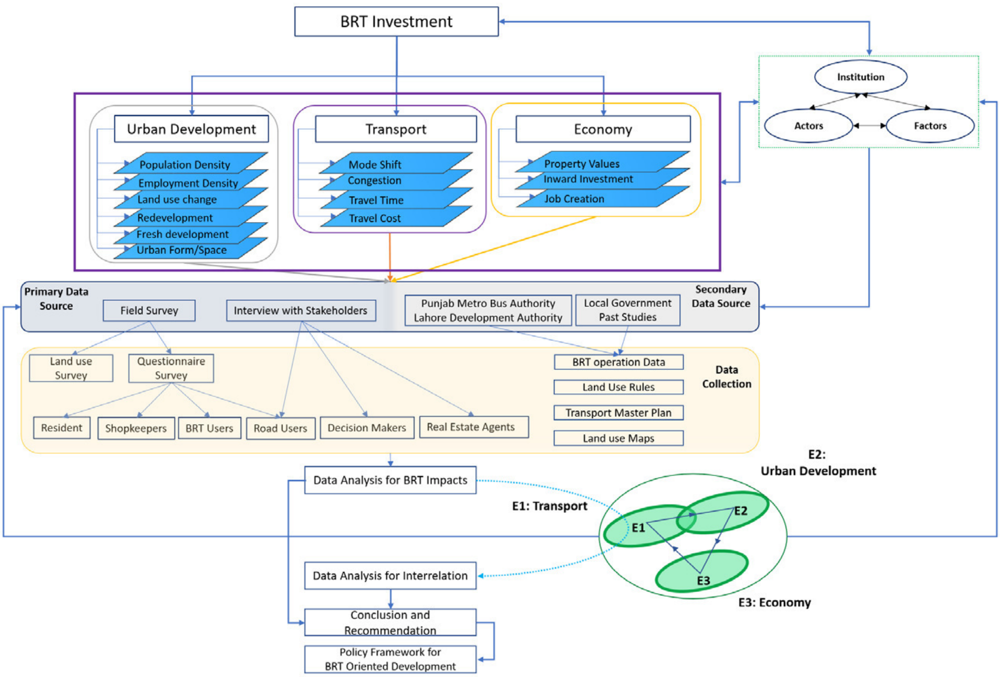


Figure 24 Detail Research Methodology

4.2 Transport Investment and Travel Behavior

Bus Rapid Transit (BRT) provides affordable and quality transportation service to the urban poor. The foremost purpose of BRT is to alter the mode choice of travelers from private vehicles. Sustainable urban transport does not primarily require the eradication of private modes of transport, but public transport must change the travel patterns of individuals (Redman, Friman, Gärling, & Hartig, 2013). Investment in transit development brought a change in the modal shift (Ewing & Hamidi, 2014; Gleave & House, 2005; Tao, 2015; Yazici, Levinson, Ilicali, Camkesen, & Kamga, 2013) and helped to elevate congestion in highly densified urban centers (Carrigan et al., 2013; R. D.

Knowles & Ferbrache, 2016; Lane, 2008). Research has shown that BRT development results in high ridership because it can attract a huge number of passengers from different modes, for instance, walking, auto, etc. (Cervero & Kang, 2011; Currie & Delbosc, 2011; Rodríguez & Mojica, 2009). The BRT system in Bogota, Colombia has shown substantial effects on congestion and transit ridership (Combs, 2017). Additionally, BRT helped to reduce automobile ownership especially for higher-income households (Combs & Rodríguez, 2014). Similar findings were observed for the US and European cases, where access to transit has resulted in the reduction of automobile use and vehicle mile travel (VMT) (Brown & Werner, 2008; Ewing & Cervero, 2010). In Jakarta, Indonesia 14% of the new passengers of BRT were previously using a personal car for their same trips (Tao, Corcoran, & Mateo-Babiano, 2013). There was a 5% reduction in private car use which has been observed in Stockholm, Sweden after the introduction of BRT (Finn et al., 2011). Empirical evidence has suggested that specific characteristics of the built environment influenced the travel pattern of people (Estupiñán & Rodríguez, 2008; Olawole, 2012). An increase in public transport use (4%) has been observed in Brisbane, Australia as a result of transit investment (Shatu & Kamruzzaman, 2014). Similarly, in Washington D.C, a 30% reduction in trips was observed in areas served by transit (Faghri & Venigalla, 2013). In Denver, Colorado an increase (61%) in the use of non-car mode was seen for people residing in the vicinity of transit (Boschmann & Brady, 2013). It was estimated in the US that 24% - 30% of travelers are those, who shifted from private vehicles to BRT (Cervero, 2013a). In Mexico, BRT has helped in stimulating a modal shift from private vehicles to public transport (Espitia, 2010).

Increased ridership significantly affects the travel time as shown in Figure 25. The highest reduction in travel time has been observed in Brisbane where a decline of more than 60% is observed (Ingvardson & Nielsen, 2018). BRT offers the benefit of improved travel time by segregating public transport operations from mixed traffic (Callaghan & Vincent, 2007; Carrigan et al., 2013; Ernst, 2005; Matata, Kitali, Sando, & Bwire, 2017). Evidence from Latin America, Asia, and Africa suggests that BRT allows an opportunity for the reduction in travel time and travel cost (Venter et al., 2018)-. Similarly, significant (7-15%) travel time saving has been observed in Vancouver (Canada), Adelaide (Australia), Leeds (UK), and Los Angeles (US) (Callaghan & Vincent, 2007; H. S. Levinson, S. Zimmerman, J. Clinger, & J. Gast, 2003; Tao, Corcoran, Mateo-Babiano, & Rohde, 2014).

Travel is a derived demand as people travel to access education, employment, and commercial activities and this choice is influenced by different factors. Al-Dubikhi and Mees (2010), and Bajracharya (2008) have examined the factors influencing the modal shift to BRT. Gender, income, trip purpose, age, and occupation are the most prominent factors influencing mode shift to BRT (Al-Dubikhi & Mees, 2010; Bajracharya, 2008; Nurdden, Rahmat, & Ismail, 2007; Vedagiri & Arasan, 2009). The mode choice of traveler is articulated by the socio-economic characteristics of users (Basheer, van der Waerden, Kochan, Bellemans, & Shah, 2019; Masoumi, 2019; Tiwari & Jain, 2012). Similarly, a study by Yagi and Mohammadian (2008) discovered that a combination of socio-economic factors and travel characteristics can better explain the change in travel behavior resulting from the introduction of BRT. Furthermore, existing literature suggests that travel characteristics, such as travel time, travel cost, and traveler's

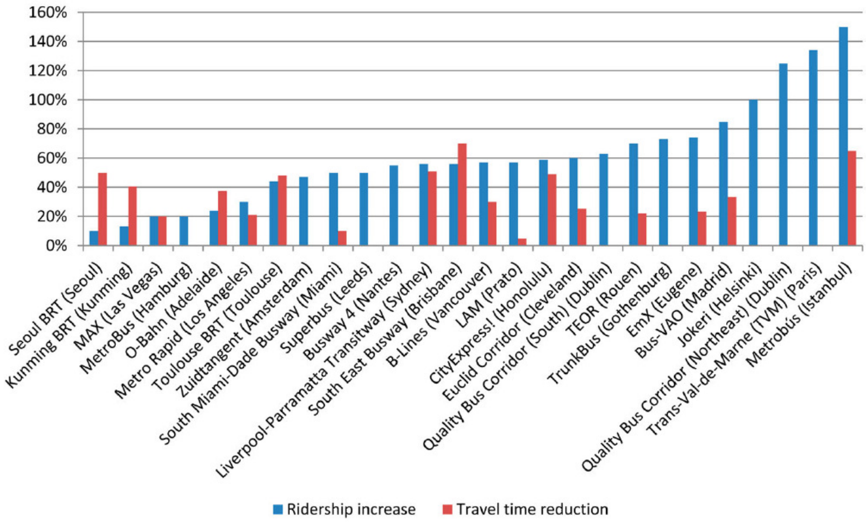


Figure 25 Relationship between ridership and travel time saving – *Source: (Ingvardson & Nielsen, 2018)*

socioeconomic characteristics including age, gender, occupation, income, and gender have an important role in the intended modal shift (Shahikhaneh, Azari, & Aghayan, 2020; Wójcik, 2019). According to Bajracharya (2008) and Yuanqing Wang et al. (2012), the factors influencing modal shift vary significantly for the different BRT systems. Therefore, there is a need to explore the factors influencing the modal shift to BRT.

Since the BRT implementation in Lahore, several efforts have been made throughout to evaluate the performance and its impacts. Rathore and Ali (2015), evaluated the BRT of Lahore against best international practices. Similarly, Aziz, Rehman, Haider, and Malik (2015), use key performance indicators such as reliability, comfort, travel time savings, and safety to analyze the performance of BRT in Lahore. Naseem (2015), examines the socio-economic benefits amplified by the implementation of BRT in Lahore. However, this study only gives the general socio-economic information and does not portray anything about the factor related to socio-economic characteristics that influence the choice of commuter. Mansoor, Zahid, and Shahzad (2016) use public opinions to highlight the positive impacts of BRT, Lahore. Nevertheless, despite these studies, BRT's ability to change the travel behavior of commuters in Lahore remains unexplored. However, the characteristics of a transport system to encourage a modal shift is a crucial aspect in the political discussion, since the main purpose of mobility investments is to shift the people from other modes like cars and motorcycles, etc. to public transport. Moreover, a modal shift to public transport is one of the main goals of transit-oriented development (TOD) (Prayogi, 2017). Since the majority of BRT systems are relatively new, therefore, empirical studies to assert their benefits are insufficient. Furthermore, limited research on BRT from the perspective of the user is evident which is crucial because social benefits provided by the transit system are the utmost justification for government investment (Venter et al., 2018; Zolnik et al., 2018). Thus, there is a need to examine some fundamental questions related to the travel behavior impact of BRT.

Figure 26 depicts the transport subsystem corresponding to the actor relational approach and that outlines the main actors, institutions, and factors involved in transportation in the case of Lahore. The actor-relational approach help in understanding the constitution of the transportation system. The main actors involved in the case of transportation include BRT users, other road users, residents, and shopkeepers along the BRT corridor. The other actors, include representatives of Punjab Metro Bus Authority (PMA), Lahore Transport Company (LTC), Traffic Engineering and Transport Planning Agency (TEPA). Policies regarding public transport and transport master plan were also analyzed to evaluate the role of plans and policies in the organization of the transport subsystem in the pre and post-BRT scenario.

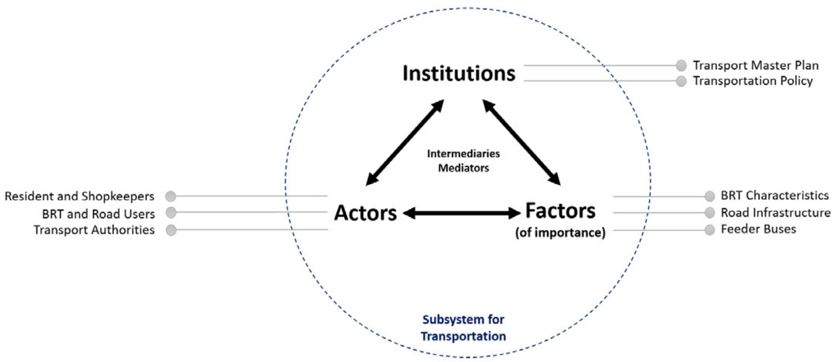


Figure 26 Transportation subsystem

4.2.1 Data Collection and Methodology for Travel Behavior

The data about travel behavior were collected from all 27 stations from four different groups i.e. BRT users, other road users along BRT, residents, and shopkeepers along the BRT corridor. This gives us the information about travel patterns of all the actors in the vicinity of BRT that could have been affected by the development of BRT. In this study, a trip is considered as a journey executed for a single purpose. A total of 1113 individuals responded and were included in the analysis. The face-to-face questionnaire survey was conducted around all the station areas to gather the information about travel patterns of various actors involved. The questionnaire was divided into five parts; (1) respondent travel characteristics, (2) socioeconomic characteristics, (3) travel frequency, (4) mode shift to BRT, and (5) factor for modal shift. Travel and Socio-economic characteristics in the questionnaire include trip purpose, vehicle ownership, age, gender, occupation, education, and income. Questions related to mode shift to BRT comprised of the previous and current mode of transport. The listed factor for the modal shift includes travel time, travel cost, comfort, reliability, safety, integration, and change in travel time and cost. For an even distribution of sample size data were collected during the different times (Peak and off-peak hour) and days of the week (weekdays and weekend). Figure 27 shows the data collected and statistical models used for the identification of factors of importance and performance analysis of BRT. Binary logistic regression analysis was applied to assess the factors affecting mode choice between BRT and other modes of transport. Further, performance analysis (ANOVA-analysis of variance) was performed to compare the mean change in travel time and travel cost for different travel modes. This gives us the cost-benefits analysis concerning different travel modes for travel time and travel cost saving.

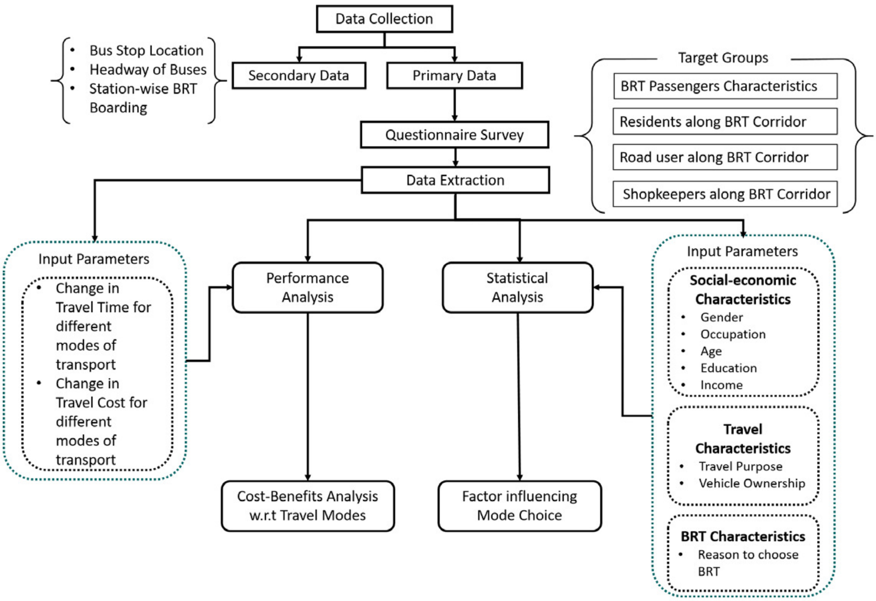


Figure 27 Methodological framework for travel behavior change

In the second stage, representatives of transport departments including Punjab Metro Bus Authority (PMA), Lahore Transport Company (LTC), Traffic Engineering and Transport Planning Agency (TEPA) were interviewed to investigate their role in pre and post BRT scenario.

4.3 Transport Investment and Urban Transformation

Public transport investment was generally perceived as mobility investment and its external benefits were mostly been ignored by the planners. However, in the last few decades, a new paradigm has emerged in the planning of the mass transit systems. This paradigm mainly focuses on the ability of mass transit to shape urban areas and to control urban sprawl which is the general growth pattern in most developing countries. Public transit services act as a counterforce to reduce urban sprawl through dense urban development (Handy, 2005). So, investment in transit services can play a crucial role in the application of Smart Growth Strategies e.g. compact development. Cities like Copenhagen and Stockholm have actively utilized their rail investments to shape their land development (Cervero & Kockelman, 1997). Similarly, other municipalities applied similar investment strategies to regenerate and revitalize major inner-city centers (R. D. Knowles, 2012). Research in the past predominantly focused on the effects of the heavy and light rail system on development patterns (R. D. Knowles & Ferbrache, 2016; Ratner & Goetz, 2013).

New growth resulting from transport investment was witnessed in Oregon, Portland (R. D. Knowles & Ferbrache, 2016). Furthermore, in Manchester (UK) recovery of CBD was coordinated by Metrolink and Central Manchester Development Corporation (C. Law, Knowles, Grime, & Senior, 1996). These kinds of interactions were also evident in France (C Hass-Klau, Crampton, & Benjari, 2004). Similar effects concerning BRT were also recognized, for instance in Curitiba, Brazil (Gakenheimer et al., 2011; D. Rodriguez & Vergel, 2013), Bogota, Colombia (Munoz-Raskin, 2010; Rodríguez & Mojica, 2009) and Seoul, South Korea (Cervero & Kang, 2011; Jun, 2012). Positive impacts of BRT on land-use were also witnessed in Brisbane, Australia, and Ottawa, Canada (H. S. Levinson et al., 2003). These examples indicate that land development due to transit investment is not limited to rail; BRT can also trigger property development. The studies in Quito (Ecuador) and Bogota show, nevertheless, that impacts of BRT on land development are context-dependent; some stations indicated much more land development activities than others (D. A. Rodriguez et al., 2016). In Bogota, for instance, impacts on urban densification were only observed in specific areas served by Transmilenio. Overall, an upsurge of 8% in density was observed between 2001-08 in Bogota (Bocarejo, Portilla, & Pérez, 2013). Similar scattered impacts of BRT on urban density were observed in urban centers of Seoul, South-Korea (Jun, 2012). Besides, real estate experts and planners in Beijing (China) perceived positive impacts of BRT on real estate activities and high-density residential developments (Deng & Nelson, 2013). The experience from Beijing, China shows that BRT has the potential to attract residential and commercial properties (Deng & Nelson, 2010b). In Bogota, Transmilenio helps in transforming station areas through the introduction of new supermarkets and shopping centers and residential uses cover 75% of new development (Bocarejo et al., 2013). Next, to that, Bogota's Transmilenio has also contributed towards the renovation of areas in its vicinity, which ultimately improved the public realm (Munoz-Raskin, 2010). This trend is different when compared with redistributive effects of Seoul's BRT that indicate movement of non-residential activities toward urban centers and only limited effect on residential activities (Jun, 2012). These findings indicate that urban development impacts of bus rapid transit are relational and context-dependent thus should be studied using a relational approach. According to Cervero and Dai (2014), the mobility function of BRT in Bogota superseded its city-making function. Nevertheless, in both cases impacts of BRT on urban development and redistribution are obvious. Thus, areas near the BRT corridor tend to be more desirable for new development as well as redevelopment. Therewith, all these studies indicated that the city structuring and shaping role of BRT is highly context-dependent (Prayogi, 2018).

But several scholars also question the potential of BRT to induce urban development (Cervero & Dai, 2014; Lindau, Hidalgo, & de Almeida Lobo, 2014; Suzuki et al., 2013), because as compared to rail operation, BRT is less accessible (Vuchic, 2007) and less permanent (Dittmar & Poticha, 2004). Consequently, property developers and entrepreneurs (e.g. retail operators) are likely to move to places served by rail lines rather than BRT. Hence, there is not an agreement between researchers on how BRT will impact surrounding areas and under which conditions these impacts are likely to occur. A few researchers even indicate that the impact of public transit cannot be fully capitalized without public policies encouraging high-density development and appropriate conditions for the real estate market (Cervero, 1984; Knight & Trygg, 1977). Moreover, higher density development around transit service depend on existing land use, the growth rate in the region, public sector involvement (Handy, 2005) land regulation, and land availability (D. A. Rodriguez et al., 2016) as seen in Bogota and Ahmadabad (India). However, empirical evidence on city-shaping impacts of BRT is still very limited and ambiguous. There remains a need to more specifically identify the land use transformation that results from BRT, especially in developing countries; since most BRT systems are implemented in these countries.

Figure 28 shows the urban development subsystem. The actor-relational approach provides the benefit of investigating the urban development subsystem through the identification of the actors, institutions, and factors involved. The actors under the development subsystem mainly include residents, businessmen, and development authorities. The main institutions to control urban growth include development plans and buildings and zoning regulations that have been prepared and amended from time to time to control the growth of the city. The factors of importance for land use transformation were identified through interviews with stakeholders.

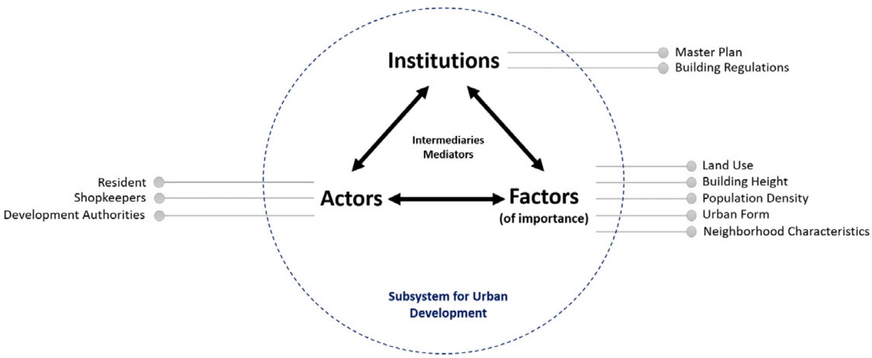


Figure 28 Urban Development subsystem

4.3.1 Data Collection and Methodology for Urban Transformation

In order to identify land use transformation after the development of BRT, 10 stations were selected having specific characteristics of all nodes and true representatives of all the stations. This selection was made through a preliminary field survey with an aim to include all income and social groups, various stakeholders around the nodes (e.g. land owner, businessmen, government). These areas around transit nodes were expected to experience significant impacts. Although the influence could spread beyond the so-called catchment areas of the nodes (circa 500 meters, 5 minutes walking), these areas attract more interest from developers (Al-Mosaind, Dueker, & Strathman, 1993; Deng & Nelson, 2010b, 2012). For urban development parameters, we have therefore studied the impacts within these catchment areas around each of the selected BRT stations.

For each of the selected nodes, a similar research methodology was adopted (see Figure 29). On every station field surveys were executed to analyze the transformation in land use between 2012-2019. Land use data were collected in 2012 by students of the City and Regional Planning Department, University of Engineering and Technology, Lahore. As BRT Lahore started its operation in February 2013, 2012 could be regarded as the reference year. To investigate the prevailing urban development trends; in 2019, land use survey was executed within 500 meters buffer of selected BRT stations. Land-use transformations between 2012 and 2019 were investigated through GIS map analysis techniques. Transformations were captured through analysis with regard to (1) land-use change (2) new development (new buildings developed on vacant land), (3) redevelopment (change in building structure or reconstruction), (4) addition of storey (redevelopment with extensions such as additional floor/storey), (5) redevelopment plus storey addition (include buildings having both 3 and 4) and (6) no change.

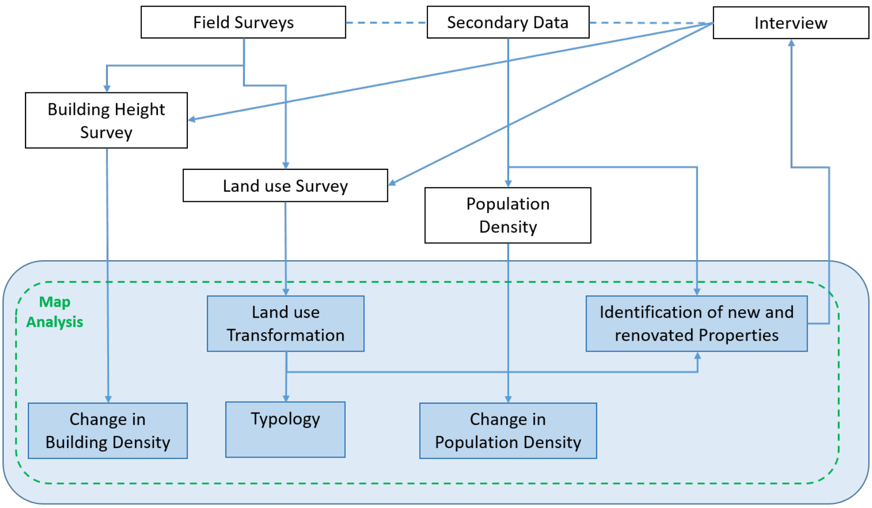


Figure 29 Methodological framework to identify urban transformation

Furthermore, additional data was also gathered regarding the added number of storeys for each property to calculate any change in property/cover area (e.g. area of the property multiplied by the number of storeys). An increase/decrease in land use was calculated and presented through maps. This also helped to illustrate the spatial location of each property with corresponding land use transformation. The change in the area of different land uses between these two moments is presented also in two ways. Simple area calculation shows the change in a land area of different land use while neglecting building heights. Whereas area height depicts the area of different land uses when building height is taken into account (calculated by multiplying the number of storeys with the area of each property). This measure gives an exact account of the area added/reduced for different land uses. All the outcomes are presented in a similar way for each of the 10 selected stations in Chapter-7. Data from the Bureau of Statistics Punjab were used to analyze any change in population density from 2011 to 2016. Besides, population density, building density is estimated by building height x property size, which is directly related to the number of persons residing in an area.

Additional face-to-face interviews were done with residents to explore the determinants of land use transformation. The interviews were then evaluated using Atlas.ti (version-7). Atlas.ti is a sophisticated and powerful tool to manage, arrange and analyze qualitative data in a systematic way. The software helps in uncovering complex hidden phenomena in qualitative data therefore, in this research, this was used to unfold the complex interrelation of land use transformation with transport and economy. In Atlas.ti various code families (themes) and codes/nodes can be defined to evaluate and weigh their importance. In order to analyze the determinants of land use transformation, the main themes were introduced as BRT impacts, the reason for transformation, and type of transformations, and then their interrelations were established with various nodes. Atlas.ti also offers the advantage to visualize the complex association between themes and nodes through mind maps. In this research, the interrelation between land use transformation, urban development, and economy is presented through mind maps. The role of different actors was assessed through interviews with officials of concerned authorities (e.g. Lahore Development Authority and municipal corporation), estate agents, and residents. Change in the institution was identified by analyzing land-use rules/regulations.

4.4 Transport Investment and Economic Development

The findings from different researches indicated that the development of new transit service induces an improvement in economic performance (Banister, 2011; Banister & Thurstain-Goodwin, 2011; R. D. Knowles, 2012) which is reflected through inward investment, the extension of the labor market, and an upsurge in property values. Banister and Thurstain-Goodwin (2011), for instance, classified non-transport economic benefits from rail investment into macro, meso, and microeconomic impacts. Macro-economic effects correspond to transport investment impacts on labor productivity, private capital, and GDP. Meso-economic impacts correspond to the agglomeration effects of economic activities and micro-economic effects of transport investment relate to the impacts on property values. At micro-scale businesses can benefit from the arrival of additional visitors and shoppers potentially spending their money in the area (Crocker et al., 2000). In this respect, the evidence from Strasbourg (France) indicated that large chain stores moved into the vicinity of transit service (C Hass-Klau et al., 2004). Findings from Manchester, Copenhagen, Vancouver, and London show that investment in light rail increases the accessibility to main employment centers, thus helping extension of the labor market (R. D. Knowles & Ferbrache, 2016). According to Fan et al. (2012), accessibility improvement to employment appended by Hiawatha light rail in Minneapolis (USA), helps to create additional 7000 jobs. Similar, effects were observed in Lima, Peru, where BRT significantly influences the opportunities of formal jobs (Oviedo, Scholl, Innao, & Pedraza, 2019). The study by Salon, Wu, and Shewmake (2014) depicted the view of real estate agents and decision-makers according to which BRT line brought additional customers and sales to the business along the BRT corridor. The literature focusing on the economic impacts of BRT is limited and needs further exploration. The researchers also suggested a change in property value as one of the externalities attached to transport investment (Pagliara & Papa, 2011). The association between rail transit and property value uplift is conclusive (Cervero & Duncan, 2002b; Gibbons & Machin, 2005; McDonald & Osuji, 1995). In some cases, the impacts of transit investment can be substantial as seen for the Jubilee line extension in London, where land value increased by £13 billion while the cost of the extension itself was £3.5 billion (Riley, 2001). Positive impacts on the property value of rail and light rail transit were also observed (Cervero & Duncan, 2002b; Debrezion et al., 2007; M. F. Dziauddin, Powe, & Alvanides, 2015; Pagliara & Papa, 2011). However, few studies have also shown depreciation in property values (Cervero & Landis, 1997; Ryan, 2005). Most of these past studies focus on the impacts of rail, metro, and light rail systems on property values as shown in Table 8. As the number of properties benefiting from transit service are limited so firms and households are willing to pay more. Therefore, access benefits underline by transit investment are capitalized into higher property values. According to D. A. Rodriguez et al. (2016), this capitalization would lead developers to invest in property along BRT as their expected benefits are higher than investing in properties elsewhere. The expansion of BRT around the world as a new transport mode has raised the question regarding its potential to influence property values. A growing body of literature attempts to explore the property value impacts of BRT. Still, there remains a lack of evidence about the property value and economic impacts of BRT.

Different researchers have established an association between BRT investment and property values. Land value impacts of BRT are evident in cities like Los Angeles (Cervero, 2013b), Bogota (Munoz-Raskin, 2010), Boston (Cervero, 2013b), Beijing (Deng & Nelson, 2010a), and Brisbane (H. Levinson et al., 2003). In Beijing, China the apartments near BRT stations have witnessed a relatively faster increase in their value. Deng and Nelson (2010a), found that properties falling within 300 meters of a BRT station have a 7.4% higher price than the properties 300 to 500 meter and 15% higher than the properties within 500 to 1000 meters from BRT station. The study by Cervero and Kang (2011), indicated a gain of 5% to 10% for residential properties falling within 300 meters of BRT station and 3-26% gain for non-residential properties (especially commercial use) falling within 150 meters of BRT station.

Table 8 Impact of Rail, Metro, and LRT on Property Values

Authors	Region/City (transit system)	Area measurement	Impacts
Nelson (1992)	Atlanta (MARTA)	100 ft from station	+ve in a lower-income neighborhood -ve in a high-income neighborhood
Gatzlaff and Smith (1993)	Miami, Florida (Miami Metro Rail)	-	Slightly +ve in high-income neighborhood and no change in low-income areas
Cervero and Landis (1995)	California (LRT)	-	No statistical difference
McDonald and Osuji (1995)	Chicago	½ mile of rail station	17% upsurge in residential property values
Benjamin and Sirmans (1996)	-	-	2.4-2.6 % decline in rent for every 1/10 mile from metro station
Lewis-Workman and Brod (1997)	Portland, Oregon	1 mile from station	+ve by $76 for each 100 feet closer to station
Lewis-Workman and Brod (1997)	Queens, New York	1 mile	-ve by $2300 with increase in every 100 feet from station
Weinstein and Clower (1999)	Texas (DART)	-	+ve for commercial properties
Bowes and Ihlanfeldt (2001)	Atlanta (MARTA)	3 miles from station	+ve property values
Cervero and Duncan, (2002)	San Jose	¼ to ½ mile from station	Increase in value by 1-4% for homes and apartments Value decrease by 6% for condominiums
Cervero and Dun-can (2002b)	Santa Clara County, California		Substantial capitalization benefits were found, on the order of 23% for a typical commercial parcel near a light rail transit stop and more than 120% for commercial land in a business district and within 0.25 mi of a commuter rail station
Weinstein et al. (2002)	Dallas Texas (DART)	¼ mile from station	+ve 32%
Cervero (2003)	San Diego (Commuter and light rail)	-	-ve from 12% to +ve 46%
Gibbons and Machin (2003)	London, UK	-	+ve 1.5% for every 1 km decrease in distance
Garrett, 2004	St Louis, Missouri	1 mile from route and station	+ve by 32% with a decrease in distance of every 10 ft from station
Yankaya and Celik (2004)	Izmir, Turkey (Metro)	-	+ve in property value
Du and Mulley (2007)	England, UK (LRT)	-	Large variations ranging from -42% to +50%
Pan and Zhang (2008)	Shanghai, China	-	Increase in property values (1.1% to 3.3%)
Duncan (2008)	San Diego (LRT)	-	Increase in property values (5.7% to 16.6%)
Bohman and Nilsson (2016)	Scania Region (Sweden)	-	+ve and high benefits for lower price segments of the market

According to Perk and Catala (2009), there exists an inverse correlation between property values and distance to a station. Their study concluded that a property 1,000 feet from a BRT station is valued at $9,745 less compared to a property 100 feet away from the station. Evidence from Guangzhou, China shows that increase in apartment value was associated with proximity to the BRT corridor (Salon et al., 2014). The studies indicated that full benefits of property value upsurge can mostly be seen after full operation of BRT and these are more evident over time. In Bogota, seven different studies indicated an impact of Transmilenio on property values, however, the magnitude of the effect differs. Table 9 gives an overview of the studies carried out in Bogota.

Table 9 Impact of TransMilenio on Property Values

Authors	Model	Results
RODRÍGUEZ and Targa (2004)	Hedonic Prices	An increase of 6.8% to 9.3% was observed for every 5 minutes moving close to BRT station
Jorge Andrés Perdomo Calvo, Mendoza, Baquero-Ruiz, and Mendieta-Lopez (2007)	Propensity score matching	For residential buildings, property values enjoy a premium between 5.8 to 17%. For commercial, this value is in the range of 257% to 367%
D. A. Rodriguez and Mojica (2008)	Regression analysis	Property value increased by 15 to 20%
J. A. P. Calvo (2017)	Interaction of pooling cross-sections across time, hedonic price model, Box-Cox transformation, and spatial econometrics	Households in Bogota received benefits of US $1965 and US $1800. For commercial properties, this benefit was US $25,740
Estupiñán and Rodríguez (2008)	-	Properties near BRT station witnessed a significant increase in property values
Rodríguez and Mojica (2009)	Before and after hedonic model	Properties in BRT catchment area have 13-14% higher value than areas not served by BRT
Munoz-Raskin (2010)	Hedonic Prices	Properties in the vicinity of feeder service experienced an increase in values

Source: Adapted from Bocarejo et al. (2013)

An increase in property values is not only related to transport effects, other factors related to geography and construction also influence the property values. These factors include the size of the property, living area, age, proximity to transport facility, location of school/park, infrastructure investment, and property location itself (Banister & Thurstain-Goodwin, 2011; Cheshire & Sheppard, 2003). Few researchers also highlighted no significant effect of BRT (Ma, Ye, & Titheridge, 2013; M. Zhang & Wang, 2013) and even observed negative impacts of proximity to BRT (Cervero & Duncan, 2002a). The study of Los Angeles Metro Rapid BRT indicates that residential properties in proximity to BRT were sold for lower price whereas commercial properties sold for high. This lower price was attributed to the newness of BRT service, the absence of exclusive right-of-way, and social deprivation of the area around BRT (Cervero & Duncan, 2002a).

Since many cities are implementing BRT therefore it's becoming inevitable to explore the full economic impacts of BRT especially, on property value as this can help to devise policies (e.g. land value capture) that can be used to fund other public development projects. As huge government resources are needed to invest in public transport projects there is increasingly a need to explore new ways to generate funds for such projects. In such a competitive environment increment tax on commercial properties could be a source of investment for other transport projects. The tax could help to achieve the goal of sustainable transport. According to T. Xu, Zhang, and Aditjandra (2016), 87.51 million yuan (US $12.76 million) revenue could be generated by implementing a 1% increment tax on commercial properties in Beijing, China.

The actor-relational approach paved the way to identify the actors, institutions, and factors involved in the case of the economic subsystem as shown in Figure 30. The main actors involved investors, employees, shopkeepers, and residents. Moreover, actors such as investors and government officers were interviewed to have their views regarding inward investment.

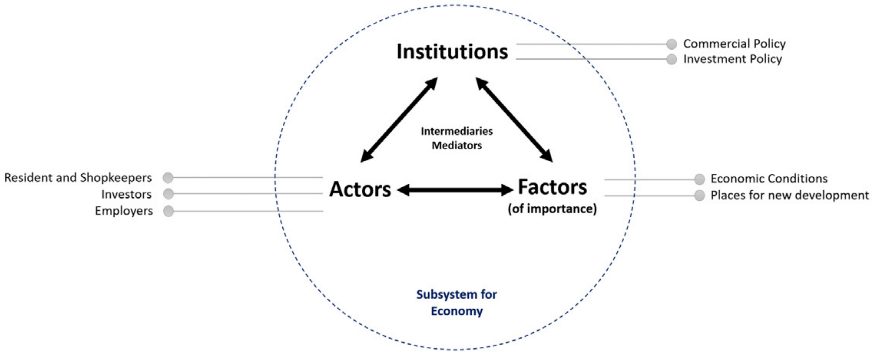


Figure 30 Economic subsystem

4.4.1 Data Collection and Methodology for Economic Development

To examine the economic impacts along the BRT route, inward investments (e.g. for commercial use) were identified through field surveys and data from local development authorities (e.g. Lahore Development Authority & Municipal Corporation). This data helped to identify the new developments along the BRT corridor. Additionally, interviews from new/renovated businesses (e.g. investor) along the BRT route was executed to explore the amount of inward investment and growth in the labor market. Moreover, the interviews with investors help to identify the determinants of inward investment. The interviews were evaluated using Atlas.ti and results were presented through a mind map which helps to visualize the interrelation between inward investment, transport, and urban development. Secondly, the economic impacts of BRT were examined through its impacts on property values. Geographically weighted regression (GWR) was applied to explore the property value impacts of Bus rapid transit. GWR has the advantage over other statistical models of taking spatial dependency into account while allowing exploration, examination, and modeling of spatial relationships. The property data are based on field surveys performed within a 500-meter buffer of BRT stations in Lahore. Data was cross-verified through District Collector (DC) rate lists and interviews with real estate agents. In total, property values data for 266 residential units were collected together with physical attributes/characteristics of the property. Base map data including BRT route alignment, feeder routes, and BRT stations was gathered from Lahore Transport Company (LTC) and Punjab Masstransit Authority (PMA). Most of the data was collected in .xls (Excel) format and was converted into .shp (shapefile) for analysis. Information regarding BRT stations and route alignment was obtained from the website https://pma.punjab.gov.pk (Punjab masstransit authority). Distance between surveyed properties and various amenities like park, hospital, school, and BRT station was calculated using GIS 10.6.1 (Geographic information system). Figure 31 shows the research flow diagram for this study and includes the methods and model used to assess the property value impacts of BRT. These interviews with stakeholders helped to investigate the interrelation between economic development, transport, and urban development.

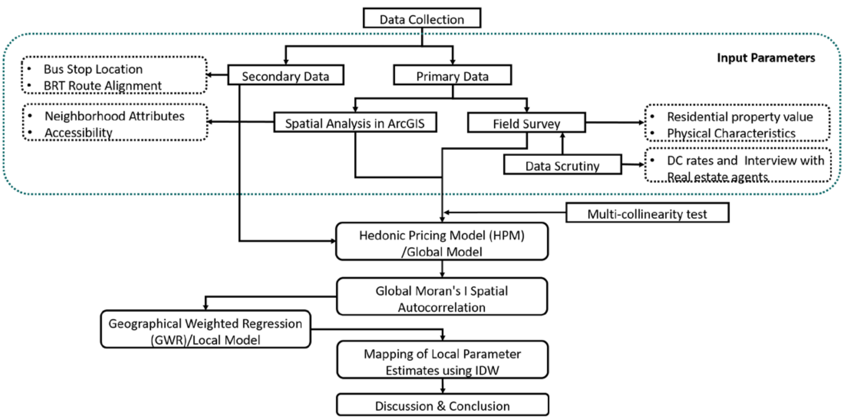


Figure 31 Methodological framework for exploring property value change

However, it is important how we utilize these interrelations between transport, urban development, and economy to achieve the goal of sustainable development. This requires the efficient use of resources and promoting growth patterns that restrict urban sprawl. The urban sprawl and problems induced by it are of top concern for many cities around the world. According to Cervero (2000b), urban sprawl is a serious barrier to accomplishing a sustainable future. In such development patterns, the transit operation becomes unviable and dependency on the private vehicles becomes inevitable (M. Zhang, 2007). In an urban environment, land use needs to be integrated with transport and vice versa. Moreover, land use should support transit operations. The economic performance of a country depends on the efficiencies of the cities which generally relies on affordable and efficient mobility services (Haque, 2014). According to Hall (1995), compact development is the key to reduce private vehicle dependency and promoting sustainable development. A high transit use can be achieved when transit impacts on land use are well integrated as shown in Figure 32. In areas where land use impacts are not triggered, transit benefits remain restricted to accessibility. A high-density well-integrated planning design is linked with higher transit service. Thus, we should utilize an integrated and relational approach to planning.

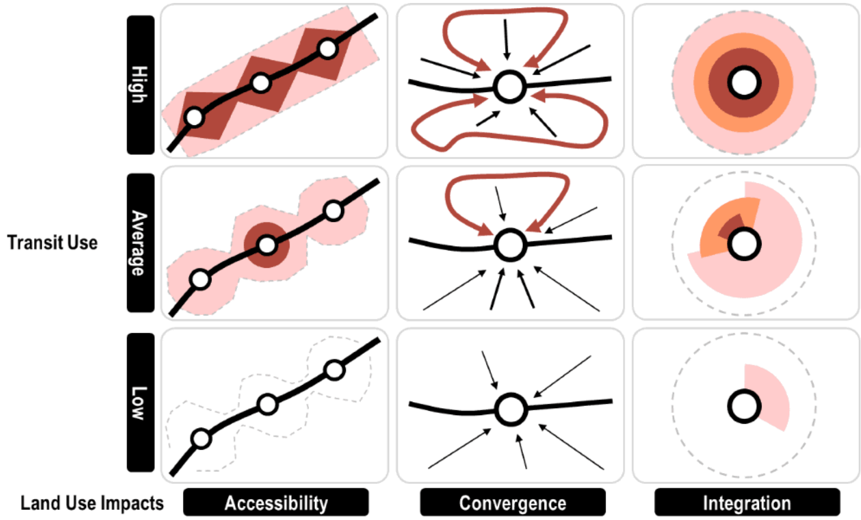


Figure 32 Transit and land use impacts – *Source : (Rodrigue, Comtois, & Slack, 2020)*

4.5 Transit-Oriented Development (TOD)

Compact development around transit nodes/stations has widely been implemented as a strategy to curb urban sprawl and to induce sustainable development often referred to as transit-oriented development (TOD) (M. Zhang, 2007). TOD has been acknowledged as a sustainable form of urbanism worldwide (Cervero & Sullivan, 2011; Renne, 2009). TOD is an approach that requires the integrating of transport, urban development, and economy. In literature, TOD is defined in a number of ways as presented in Table 10.

However, the basic idea of TOD remains the same that is to establish a built environment around transit stations with mixed-used developments that provide relatively higher densities at the same time linked with cyclist and pedestrian-friendly amenities. Thus, transit service operation is better supported and relational with land use planning. In literature, for TOD an average distance of ¼ to ½ mile (M. Zhang, 2007) or 2000 foot (Hess & Lombardi, 2004) is considered to be effective. TOD is beneficial both for private developers and transit agencies. Private developers can benefit from boosted sales volume and profitability whereas transit agencies can benefit from improved ridership (Hess & Lombardi, 2004; Vickerman, 2008). Additionally, TOD provides the benefits of increased public safety, increased walkability, reduced VMT (vehicle miles traveled), reduced air pollution, economic development, mobility choices, affordable housing (Hess & Lombardi, 2004; Parker, McKeever, Arrington, Smith-Heimer, & Brinckerhoff, 2002). Figure 33 shows the basic principles of transit-oriented development.

Table 10 Definition of TOD

Author	TOD Concepts
Salvesen (1996)	Development around a transit station providing the opportunity for diversity of land uses in a specified geographical area.
T. Still (2002)	A mixed land use development encouraging people to live around the transit services at the same time decreasing dependence on a private vehicle.
Cervero, Ferrell, and Murphy (2002)	A transit-oriented development (TOD) is mainly designed to enhance the use of public transport/transit and to create an urban setting providing a pedestrian-friendly environment.
Loo, Chen, and Chan (2010)	Under the guiding principles of transit-oriented development (TOD), the basic ideas are to design an urban form in a relatively high density, compact and mixed form, and to provide high quality, efficient mass transportation services, together with a pedestrian-friendly environment.
Claudio Sarmiento (2014)	Transit-oriented development is dense, mix-used development that provides good biking and walking connections in the city, particularly areas served by transit facilities.
Ngai Weng Chan (2016)	Transit-oriented development is the creation of walkable, compact, and mixed-use communities around a high-quality transit facility.

Figure 33 Principles of Transit Oriented Development – *Source: (Mulukutla, 2014)*

The experience has revealed that transit benefits cannot be recognized automatically and require a web of supportive strategies/policies (Cervero, 2004b; Hess & Lombardi, 2004). The role of transit agencies and local governments has particularly been discussed in the literature. Transit agencies and local governments can promote

TOD through various means. Cervero (1998), highlighted the importance of assisting land assembly, establishing agreements for shared parking, and providing financial incentives to support TOD. Special zoning provisions, publishing design guidelines for TOD, air rights, and tax credits are the measures required by local government to generate TOD (Porter, 1998). The experience from Curitiba, Brazil, and Ottawa, Canada has shown that it is accessibility gains that drive development, and bus rapid transit (BRT) can promote TOD equally to that of light rail transit. However, proactive intelligent planning is the key to establish a successful TOD (Cervero, 2000b). Curitiba, Brazil is considered the best example of transport and land use integration and co-development. The key features of Curitiba's TOD plan include comprehensive land-use policy encouraging mixed residential-commercial development with zoned densities tapering with distance from the BRT (see Figure 34) coupled with control and incentives technique (e.g. transferring development rights, the involvement of firms for large scale development, and incentives for developer providing higher residential density near BRT). Additionally, the parking policies help in enforcing the TOD plan. Limited and expensive road-side or off-street parking is provided in the central area to restrict the use of private vehicles and to encourage transit use (Lindau, Hidalgo, & Facchini, 2010).

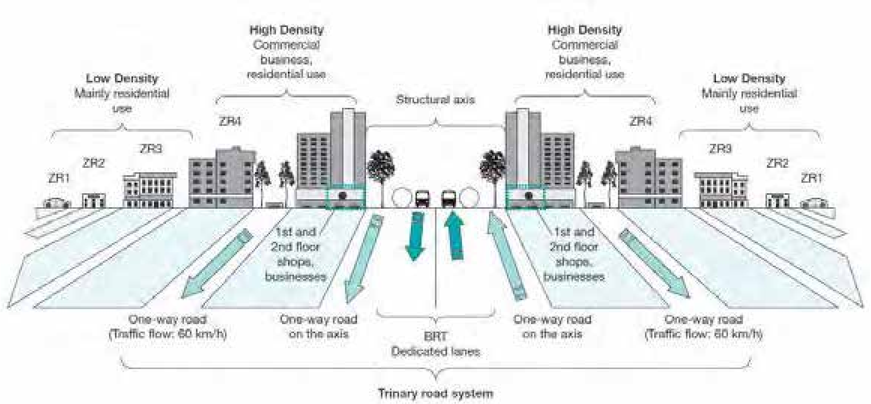


Figure 34 Trinary road system in Curitiba, Brazil – *Source:(Cooke, 2016)*

M. Zhang (2007), proposed a 5D2 model to promote transit-oriented development in Chinese cities. These 5D2 correspond to differentiated density, dockized district, delicate design, diverse destination, and distributed dividends. Differentiated density referred to the differential in density from locations outside and inside of TOD. A tapering in density while moving away from transit. Dockized districts are linked to the people's willingness to walk and activities should be promoted in these TOD districts. Delicate design stresses upon the physical setting of urban spaces which should provide pedestrian friendly environment. The fourth component require access to multiple urban functions and services through transit. Lastly, ask for distributed dividends which means that transit economic should be sustainable enough to support its operation.
According to P. P. Kumar, Sekhar, and Parida (2020), diverse applications of TOD exist in different contexts. For example, in the U.S. TOD mainly focuses on urban sprawl and centralizing density (Ewing, Tian, Lyons, & Terzano, 2017). TOD in European cities emphasis on redevelopment activities in the existing neighborhood for providing active

transport (Singh, Lukman, Flacke, Zuidgeest, & Van Maarseveen, 2017). Whereas in Asia, the land value capture technique is considered TOD (Cervero & Murakami, 2009). Cervero and Dai (2014), highlighted perceived barriers and tools used to leverage TOD by surveying 27 cities with BRT system (see Figure 35).

The most commonly used tool to leverage TOD was targeting infrastructure improvement. In most cities zoning incentives including density bonuses and relaxed zoning restriction near BRT stops were used as a tool to stimulate TOD. Similarly, allocation funds for TOD, tax increments, and value capture techniques were used as an effective tool to promote TOD. In contrast, weak institutional support and lack of financial resources were identified as major impediments to leverage TOD.

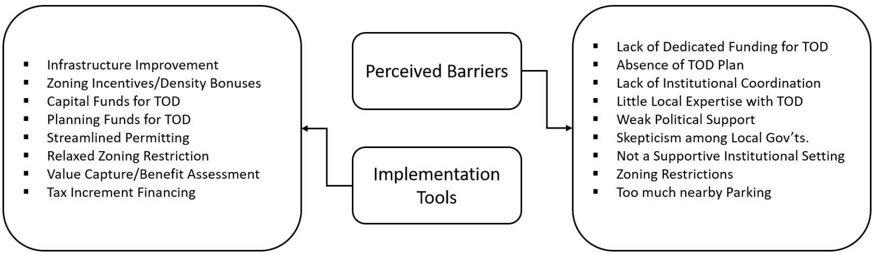


Figure 35 Perceived Barriers and Implementation Tools – *Source: adapted from (Cervero & Dai, 2014)*

4.6 Study Area

Urban sprawl is one of the problems being faced by many cities around the world. This is the result of rapid urbanization. Pakistan is also facing the issue of unplanned and rapid urbanization. Around 36% of Pakistan's population is living in urban areas which is the highest in South-Asia (UN, 2018). This rapid urbanization asked for effective utilization of limited urban space (J. Zhang & Feng, 2018). Cities in Pakistan are facing constraints toward balanced spatial growth. The weak urban planning has resulted in an unplanned expansion of urban areas (Yuen & Choi, 2012). Lahore being the second urbanized city is also facing innumerable urban problems despite having a highly developed infrastructure. This is because of the absence of an integrated plan for transport and urban development. In 2013, Lahore has received its first rapid transit system as Bus Rapid Transit (BRT), however, no effort has been made to identify and integrate the external benefits of this investment. This is similar to what is observed in Ahmedabad, India (Cervero, 2013c). According to J. Zhang and Feng (2018), to promote sustainable urban development its is important to encourage transport-focused urban development especially in Asia. Like other South-Asian cities, Lahore has polycentric urban development with dispersed job centers (Haque, 2014) which makes it a representative of South-Asia. Moreover, in most of the South-Asian cities, there does not exist a connection between transport and urban development. Thus, BRT, Lahore has been selected as a case to identify the external benefits associated with transit investment and to provide a way forward to integarete them for the creation of sustianble neighborhoods. Moreover, the BRT system in Lahore is the first of its kind in Pakistan. Authorities have planned to implement new transit systems in Lahore under the guidelines of the Lahore Urban Transport Master Plan-2012. Therefore, this study can help policymakers, investors, urban and transport planners to gain deeper insight into the urban transformation and economic impacts of the BRT system as such in Lahore. The findings of this study can help policymakers to envision the potential impacts of future projects, which can be incorporated at an earlier stage of project planning. Last but not least, the BRT Lahore, was inaugurated in recent times (2013), long ago enough to discover some additional impacts, but not too long ago to make the investigation outdated.

4.6.1 Bus Rapid Transit in Lahore, Pakistan

Lahore is a historical city situated in the northeast of Punjab. It spans over an area of 1,772 square kilometers. Lahore is the capital of Punjab province and 2nd largest city of Pakistan with a total population of approximately 11 million in 2017 (Pakistan Bureau of Statistics, 2018). Lahore is divided into 9 towns and a cantonment for administration. Now-a-days, Lahore is the hub of economic activities in Punjab with a GDP of $84 billion. The first Bus transit system (BRT) locally named Metro Bus service in Lahore started its operation in 2013. It's spanning over a length of 27 km (from Gajjumata station in the north to Shahdara station in the south) as shown in Figure 36. The BRT system was constructed with a cost of almost US$ 19 million (30 billion PKR) (Rana, Bhatti, & e Saqib, 2017). The elevated section of the route spans over 15.4 km whereas the on-ground section covers a distance of 11.6 km. The BRT route connects important commercial centers and fulfills the mobility needs of commuters; workers, students, businessmen, and shoppers. Sixty-four buses are running on the BRT route with a headway of three minutes and an average daily ridership of over 133,000 (PMA, 2020). The system was initially planned for a demand of 9,000 passengers per hour per direction (pphpd). BRT, Lahore has already surpassed this mark with an average ridership of 10,000 pphpd. There are 27 stations along the route of Lahore's BRT (see Figure 36). The BRT runs with a maximum speed of 45 km/hour, commercial speed of 26 km/hour, and intersection speed of 25 km/hour. To enhance the utilization of BRT, feeder services were also started in March 2017. Rout of BRT feeder services is shown in Figure 37. There are 162 feeder buses that run along the BRT route with a headway of 5-10 minutes. These feeder buses carry average daily ridership of 33,707. The total cost of traveling on BRT is 20 rupees ($0.1293). The travel cost of traveling on the feeder route is 15 rupees ($0.0970). A combined journey between feeder service and BRT costs 20 rupees in total ($0.1293). The passengers using feeder bus service then BRT followed by feeder bus service travel (three stages) will have to pay 25 rupees ($0.1617) (PMA, 2019). The system is equipped with various ITS technologies.

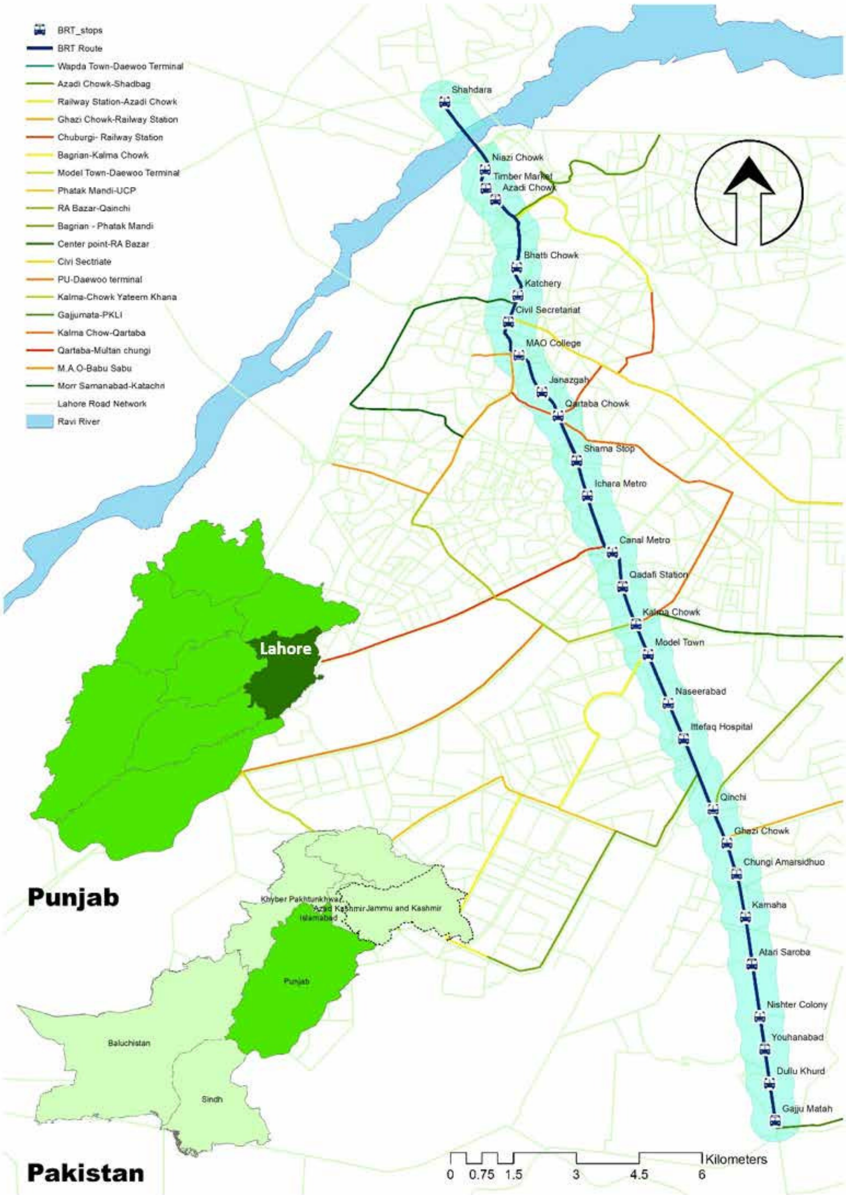


Figure 36 Bus Rapid Transit Route Alignment

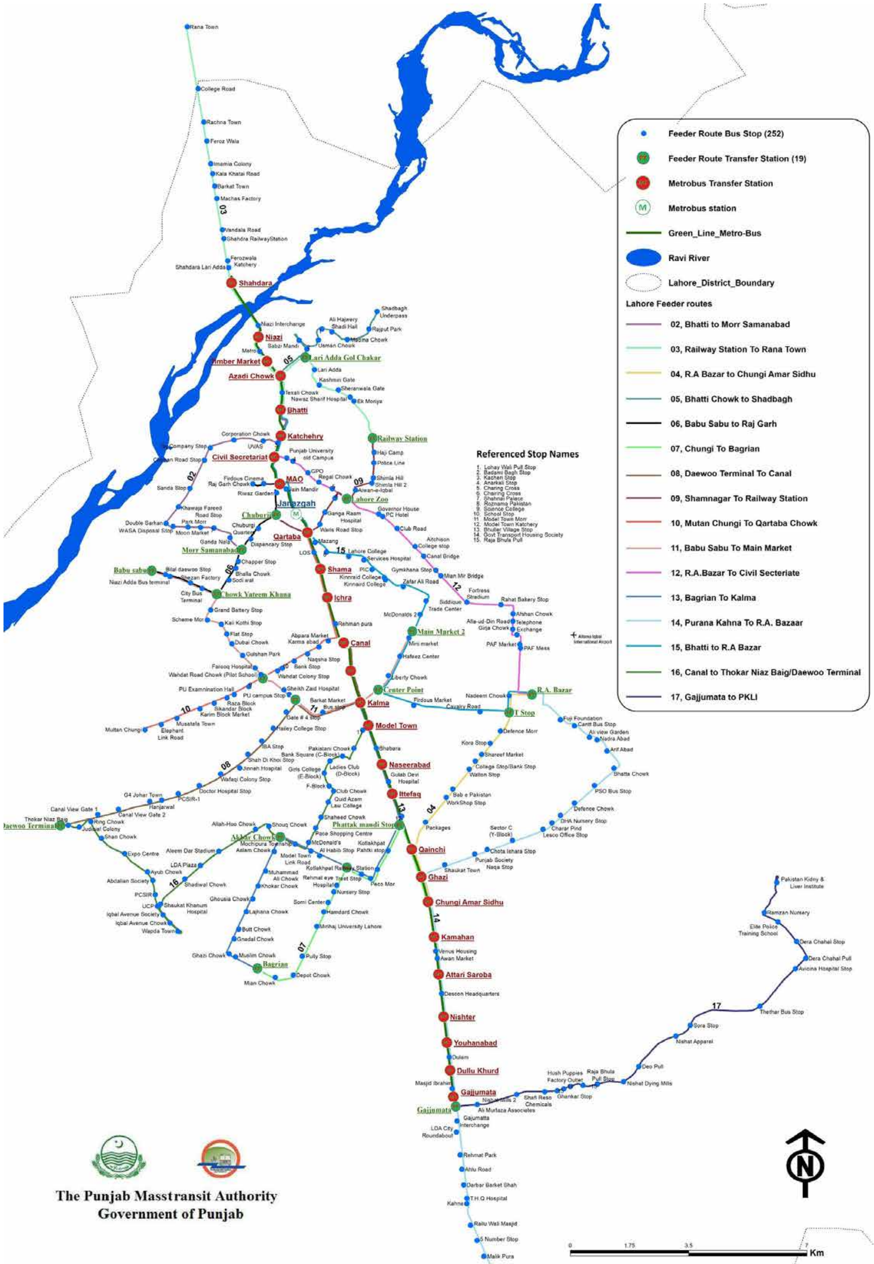


Figure 37 Feeder Bus Services Route Plans – *Source: Punjab Mass Transit Authority (PMA), 2019*

4.7 Summary

The previous researches suggested that investment in transit facilities has impacts on neighboring areas. These impacts can be classified into travel behavior, urban development, and economic impacts. Therefore, a literature review encompassing the impacts of transit development on urban development, travel behavior, and economy has been presented in this chapter. The main goal of any transit system is to change the travel patterns of individuals and to shift them from private vehicles to more sustainable modes of transportation. Investment in transit services helps to alleviate congestion in highly densified urban centers. Existing literature suggests that travel characteristics (e.g. travel time, travel cost) and socio-economic characteristics (e.g. age, gender, income, occupation) play an important role in the intended modal shift. Moreover, investment in public transit serves as a counterforce to reduce urban sprawl. It is evident from the previous researches that an increase in urban density, new development, redistribution, redevelopment, regeneration, and revitalization are some of the phenomena linked to transit development. It is also evident from experience that implementation of new transit service induces an improvement in economic performance which is reflected through inward investment, the extension of the labor market, and improvement in increased property values. As the number of properties benefiting from transit service is limited so firms and households are willing to pay more. Therefore, access benefits underline by transit investment are capitalized into higher property values. Since the majority of the BRT systems are relatively new, therefore, empirical studies to assertions on their external benefits are insufficient. Furthermore, limited research on BRT from the perspective of the user is evident which is of main concern since social benefits provided by the transit system are the utmost justification for government investment. The literature review indicated that empirical evidence on city-shaping impacts of BRT is still very limited and ambiguous. Last but not the least, most of these studies focus on the direct impacts of transit investment ignoring the interrelation between the impacts of transit investment. In an urban setting, everything is relational thus the interrelation between these impacts should also be taken into account when studying the impacts of transit investment. Therefore, there remains a need to more specifically identify the travel behavior, urban development, and economic impacts of transit investment and interrelation between them. In most of the developed countries, the interrelation between transport and land use planning is mostly been ignored which results in inefficient use of the resources. In this regard, transit-oriented-development (TOD) can help to achieve the goals of sustainable development by promoting transport and land use integration. Subsequently, Bus Rapid Transit (BRT), Lahore has been selected as a case study to explore BRT impacts and their interrelation.

5

Paradigms of Urban Governance System

5.1 Introduction

Pakistan is the world's 5th most populous country located in South Asia officially named as Islamic Republic of Pakistan (UN, 2019) with an urbanization share of 36.4 percent; highest in South-Asia (UNDP, 2019). It spans over an area of 881,913 square kilometers with a population of 207,774,520 (212.2 million) (Pakistan Bureau of Statistics, 2018). Pakistan shares its border with Iran (South-west), China (North-east), Afghanistan (west), India (East), and has coastline along Arabian Sea (South) as shown in Figure 38).

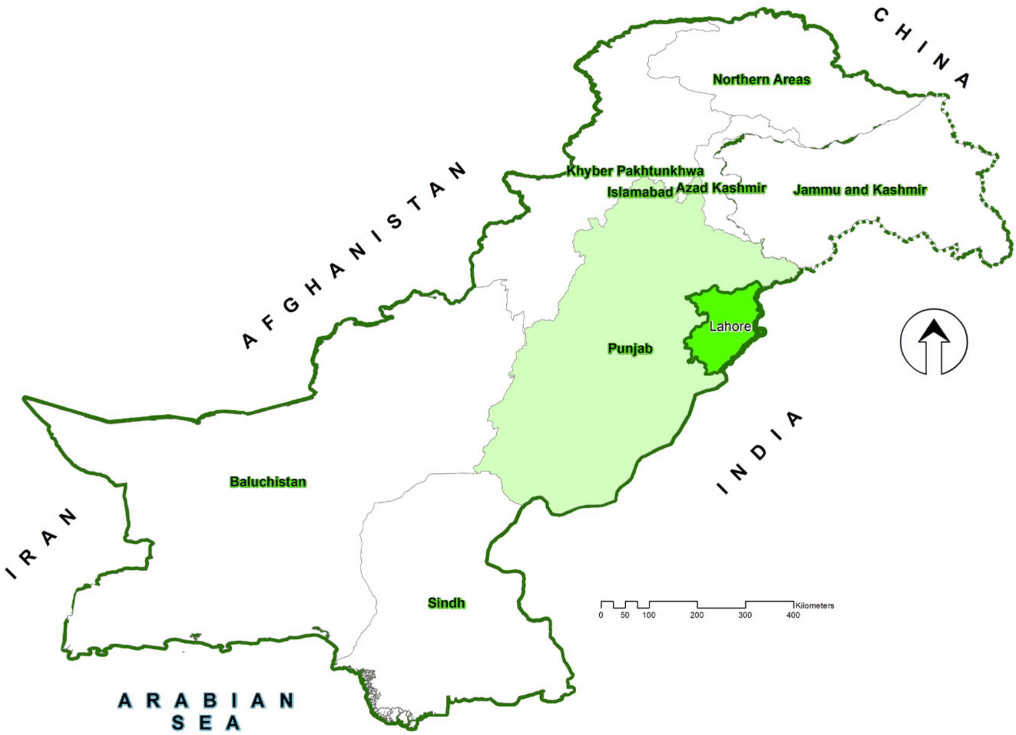


Figure 38 Location of Pakistan

Administratively there are six tiers in Pakistan.

Figure 39 Administrative tiers in Pakistan

The country is divided into four provinces (e.g. Punjab, Sindh, Khyber Pakhtunkhwa, Balochistan), one capital territory (e.g. Islamabad Capital Territory), and two self-governing units including Azad Kashmir and Gilgit-Baltistan. Figure 39 shows the different administrative units of Pakistan. Punjab is the most populous province of Pakistan with a population of 110,012,442 and covering an area of 205,344 (Pakistan Bureau of Statistics, 2018). Punjab is famous for its agricultural activities. Provinces are then divided into divisions. There are 36 division details of which are presented in Table 11. Divisions are further divided into districts, towns/tehsils, and union councils. Examples of various administrative units are presented in Figure 40.

Table 11 Details of Division

Punjab	**Khyber-Pakhtunkhwa**	**Sindh**	**Balochistan**	**Gilgit-Baltistan**	**Azad Jammu Kashmir**
Bahawalpur	Bannu	Banbhore	Kalat	Gilgit	Mirpur
Dera Ghazi Khan	Dera Ismail Khan	Hyderabad	Makran	Baltistan	Muzaffarabad
Faisalabad	Hazara	Karachi	Naseerabad	Diamer	Poonch
Gujranwala	Kohat	Sukkur	Quetta		
Lahore	Malakand	Larkana	Sibi		
Multan	Mardan	Mirpur Khas	Zhob		
Rawalpindi	Peshawar	Shaheed Benazirabad	Rakhshan		
Sahiwal					
Sargodha					

Urban governance can be divided into several major development periods to be distinguished in reference to transport and urban development.

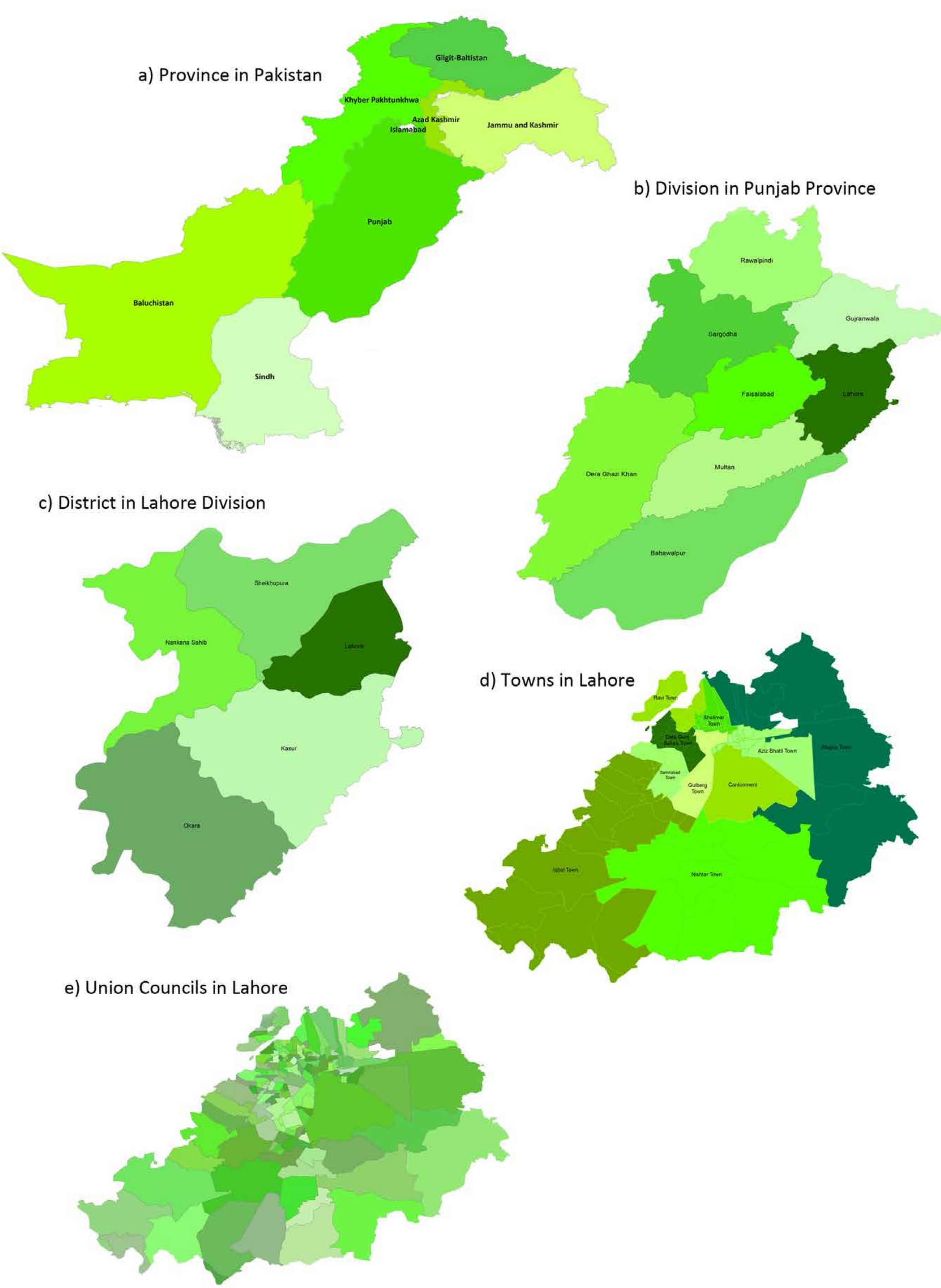


Figure 40 Administrative units in Pakistan

5.2 Period 0. Coming out form the British Empire and Independence

Lahore shares its roots back to 630 AD (JICA, 2012). Punjab was then ruled by Rajputs until it was invaded in 988 A.D. by Subaktagin. Later on the successor of Subaktagin, Sultan Mahmood invaded Lahore and Malik Ayaz was appointed as the Governor of Punjab who is also recognized as the founder of Lahore on Muslim tradition. During Sultan Masud III (1099-1114 A.D.), Lahore became the capital of the Kingdom of Ghazna. Later on, Punjab and Lahore were invaded by many rulers like Mongols, Khilji's, Tughlaq, Khokhars, Lodhi, and Mughal (NESPAK, 2004). In the Mughal rule, Lahore was described as the commerce center (H&PP, 1973). All military operations were administered from Lahore and a wall was constructed around the city known as the walled city. The development of Cantonment and Civil lines in 1857 during the British Empire was the first step towards urbanization in Lahore. After the death of Sikh ruler Ranjit Singh, the British Army entered Lahore in 1846 A.D (Glover, 2008). Under the British era, in 1861, the construction of the Lahore railway station was completed with a line providing public transportation between Lahore and Amritsar (Glover, 2008; NESPAK, 2004). The municipal committee for Lahore was established in 1862. New gardens, colleges (Government College, Punjab University, King Edward College, Maclagon Engineering College (now UET), and many others), Library (Quide-Azam Library), hospitals (Mayo Hospital), water supply service, Lahore electric supply, Irrigation research institute, the high court were initiated by British rule. In order to administer the urban growth of the city, Lahore Improvement Trust (LIT) was established in 1936 (NESPAK, 2004).

Lahore has gone through major developments during several eras i.e. Hindu, Mughal, and British rule, and even after the creation of Pakistan in 1947. Sub-continent partition in 1947 brought a major change in the physical and socio-economic setup of Lahore. During this partition, major migration trends were observed where around 40% of inhabitants migrated to India and proportionate refugees arrived in Lahore. The Punjab region got divided into two regions Pakistani and Indian Punjab (NESPAK, 2004).

The first national assembly of Pakistan was constituted as the constituent assembly of Pakistan with the purpose to formulate the constitution of the Republic of Pakistan (NAP, 2020). However, this assembly faced many difficulties while governing East (Now Bangladesh) and West Pakistan (Pakistan) effectively. In 1954, the constituent assembly was dissolved and the second constituent assembly was reconstituted in 1955. In this year first five-year plan (1955-1960) was approved for the national-wide economic development of Pakistan with a major focus on industrialization. The first constitution of Pakistan in 1956 and Pakistan became the Islamic Republic. However, this constitution did not last long and abrogated by martial law in 1958 (NAP, 2020).

5.3 Period 1. Struggling with the new state & Civil War

A new constitution was outlined in 1962. In this constitution, the presidential government system was brought as opposed to the parliamentary system. (NAP, 2020). Under the 1962 constitution Presidential election was held in 1965 which resulted in the victory for Ayub Khan. In 1965, war broke out between Pakistan and India on the issue of Indian-occupied Kashmir. In East Pakistan, Sheik Mujibur Rahman leader of the Awami League started his six-point movement. In 1968, Sheik Mujibur Rahman was put in prison and was charged with sedition. This was the start of the civil war in East Pakistan. Under pressure from West and East Pakistan, President Ayub Khan handed over the charge to Yahya Khan (Commander in Chief of Pakistan Army). In 1970, President Yahya Khan announced direct elections through Legal Framework Order (LFO). The unequal distribution of resources and grave political differences between the Awami League and the Pakistan People's Party resulted in the separation of East Pakistan (now Bangladesh) in 1971 (NAP, 2020).

During this period particular attention was given to control and guide urban development. Since independence, Lahore's growth and development was managed by municipal administration and improvement trust but there was no town planning for improving development control in the city. In 1960, Municipal Administration Ordinance was approved outlining the power of the local councils to exercise development control (Rana et al., 2017). Moreover, the second five-year plan (1960-65) envisioned the preparation of master plans for eleven cities in Pakistan. Lahore topped this list as a provincial metropolis. Realizing the shortcomings of Lahore Improvement Trust (LIT) and Lahore Municipal Corporation, Provincial Government decided to set up a Master Plan Committee.

5.3.1 Master Plan for Greater Lahore

The analysis in the master plan revealed that unplanned and uncoordinated growth were the main problems in Lahore. Poor transportation, sanitation, encroachments, other community facilities were other problems. The first master plan was completed in 1966 and was submitted to the provincial government for vetting and approval. However, the plan was not approved until 1970 due to poor political will. After that, a working group was established to review the Master Plan. Revision of master plan was indispensable because of delay in process of approval and change in geographical characteristics because of war between Pakistan and India in 1965. This group could not complete its task. Therefore, A new working group was reconstituted in 1971. The plan was admired by the working group with few amendments. The first master plan for Lahore was sanctioned in 1972 titled "Master Plan for Greater Lahore" under Municipal Administration Ordinance (H&PP, 1973).

In the Master Plan for Greater Lahore, the city was conceived as a metropolitan area with many satellite towns around it within a distance of 20-25km. A green belt of 24km was proposed to segregate the urban development of Lahore from surrounding towns

(NESPAK, 2004). However, lack of development control and backlog in transport demand and supply resulted in linear growth. Figure 41 shows the master plan of Lahore prepared in 1966. A major development in this master plan was proposed in the direction of the south and south-west. Eastern direction was restricted for any development beyond the airport because of proximity to the Indian border. In the end, this master plan failed to fulfill its goal because of the lack of interest of authorities.

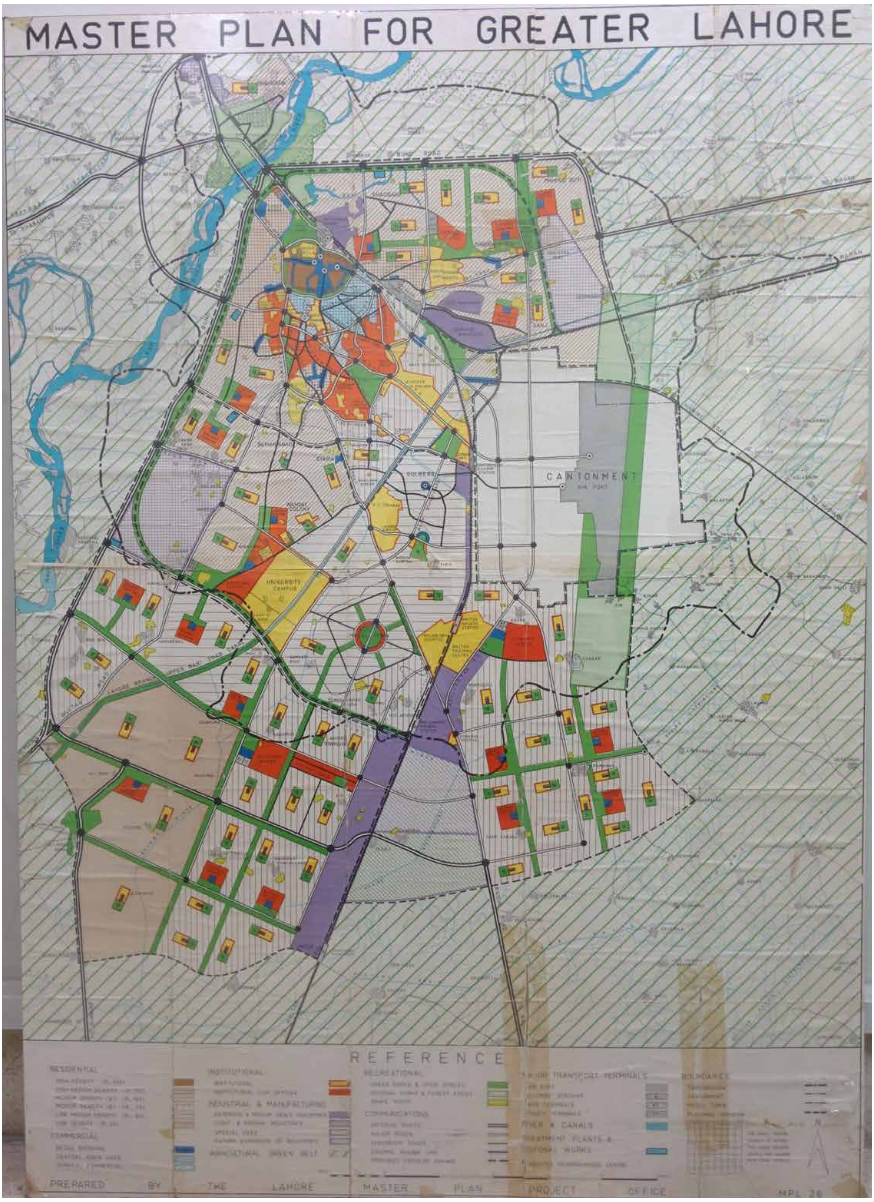


Figure 41 Master Plan for Greater Lahore-1966 – *Source: Lahore Development Authority, 2019*

5.4 Period 2. Inception of Democracy

The election in 1971 was the first step toward real democracy as Mr. Zulfiqar Ali Bhutto was elected as President of Pakistan (NAP, 2020). As one of his first things, Bhutto announced was the nationalization of major industries (Burki, 1974). A new constitution was approved in 1973 and the government system was again introduced as a parliamentary democracy system as that of 1958. Mr. Bhutto takes over the charge as Prime Minister of Pakistan (NAP, 2020). In this period some new organizations including Housing and Physical Planning Department, and Lahore Development Authority were constituted to promote planning and development control.

5.4.1 Housing and Physical Planning Department (H & PP)

In 1972, the Housing and Physical Planning Department (H & PP) was constituted by substituting the West Pakistan Housing and Settlement Agency having one attached department as Directorate General Housing and Physical Planning in Lahore. Improvement Trusts in Punjab were converted to Development Authorities except for Sargodha and Murree (GOP, 2016).

5.4.2 Lahore Development Authority (LDA)

Lahore Improvement Trust (LIT), was controlling the urban development patterns in Lahore from 1936 till 1975. Then LIT was metamorphosed to Lahore Development Authority (LDA) (H. B. Malik, 2014). LDA is established under LDA Act 1975 to undertake planning and development control in the metropolitan area of Lahore. The main goals of LDA are to ensure sustainable and integrated development, quality and low-cost housing, maintain the beauty and aesthetic of the city, rehabilitation of slums, and encouraging environmental friendly activities through an appropriate system of sanitation/drainage and traffic (e.g. integrated traffic management system) (LDA, 2020; NESPAK, 2004). Currently, there are three wings of the Lahore Development Authority (LDA) as shown in Figure 42.

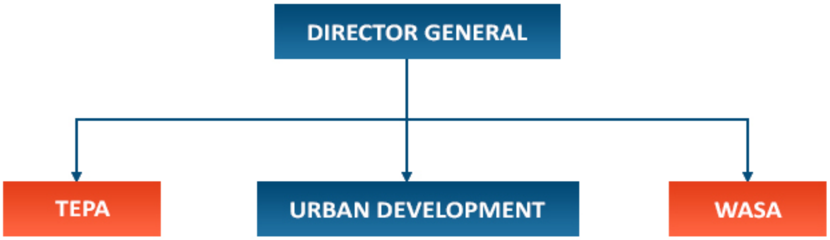


Figure 42 Wings of Lahore Development Authority (LDA) – *Source: (LDA, 2020)*

i. Urban Development

The Urban Development wing of LDA besides planning and development control is also responsible for the provision of quality and low-cost housing. All policy documents like the master plan and building bye-laws are prepared by the urban development wing. Master plans serve as a policy document to control the growth of the city whereas, building bye-laws (building code) provide guidelines for the development of an individual building (e.g. building height, floor area/cover area, building structure).

ii. Water and Sanitation Agency (WASA)

The second wing of LDA is the Water and Sanitation Agency (WASA) which was established in 1976 for planning, designing, development, and maintenance of clean water supply, draining, and sewerage system (WASA, 2020). The details about TEPA are presented in the next section.

5.5 Period 3: Martial Law

In July 1977, General Zia-ul-Haq derailed the democracy by suspending the constitution (NAP, 2020; Wynbrandt, 2009). Under Zia's regime, the country experienced the highest growth rate in the world i.e., 6.8%. After eight years, martial law was lifted in 1985. Muhammad Khan Junejo became the Prime Minister of Pakistan. However, General Zia kept the power to dismiss Prime Minister and to dissolve the assembly. Afterward using his power, General Zia dismissed Junejo and his government in 1988 and called for a new election. But he could not saw elections materialize as he died in August 1988 as a result of a plane crash (Nasr, 1994). During this period following main policy documents and departments were established for transport and urban development in Lahore.

5.5.1 Lahore Urban Development and Traffic Study (LUDTS), 1980

The second policy document for Lahore was prepared in 1980 which was mainly a structure plan (does not include detailed allocation of land uses). However, special focus was on the development of plots for low-income groups. In this plan special consideration was given to transport, and also encouraged integration between urban development and transport for the first time. The future development was proposed in the south and south-west direction as shown in Figure 43. Major transport initiatives proposed in the plan was related to the development of transport infrastructure (e.g. development of secondary and tertiary road) (JICA, 2012; NESPAK, 2004). No special measure was suggested to cater to growing travel demand and issues of public transportation which are of great importance especially for the urban poor (JICA, 2012).

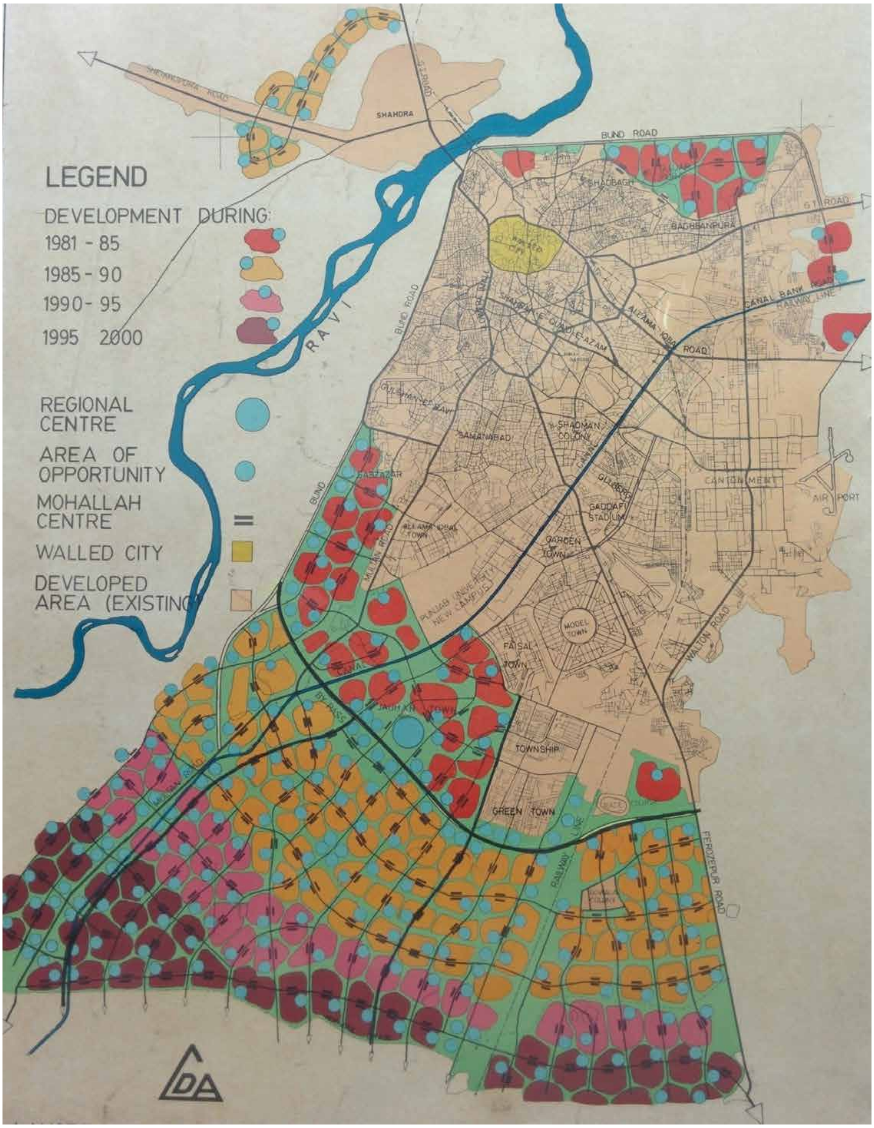


Figure 43 Lahore Urban Development and Traffic Study-1980 – *Source: (NESPAK, 2004)*

5.5.2 Transport Department (TD)

As a result, the Transport Department was established in 1987. The transport department is responsible for the implementation of policies devised by the government for the provision of comfortable, affordable, and efficient transport services in the entire province (Punjab) (TD, 2020). This also regulates fares of public transport and prepares development plans for public transportation. Since the government has limited resources to invest in public transport. Therefore, the transport department encourages private operators to assist the government in providing public transport services. The transport department provides subsidies to these private operators to maintain minimum fares for the urban poor (JICA, 2012; TD, 2020). In the Lahore metropolitan area, these subsidies are regulated by Lahore Transport Company (LTC).

5.5.3 District Regional Transport Authority (DRTA)

Initially, District Regional Transport Authority (DRTA) was regulating public transportation in the Lahore district before the constitution of Lahore Transport Company (LTC). Regulation of all types of transport, classification of routes, and issuance of route permits are the major tasks of DRTA. Since, DRTA was not effective in the provision of public transport because of the underdeveloped system of public transport, fragmented, inefficient, and inadequately managed (LTC, 2018) therefore, in Lahore its functions were replaced by LTC.

5.5.4 Traffic Engineering and Transport Planning Agency (TEPA)

The Traffic Engineering and Transport Planning Agency (TEPA), is a subsidiary body of Lahore Development Authority (LDA) constituted in 1987 (JICA, 2012; TEPA, 2018). TEPA was created to perform traffic engineering and transport planning projects in Lahore. TEPA is responsible for the development of traffic and transport infrastructure in Lahore. TEPA is performing its duty to resolve traffic-related problems through improvements in road geometry and traffic signals (TEPA, 2018). Following are the major function performed by TEPA:

- Transportation Planning
  Prepare and coordinate transportation plan for Lahore
- Traffic Engineering
  - Planning, designing, and implementing traffic management and traffic engineering programs
  - Advise other transport agency or authorities to take traffic control measure
  - Design, install, control, and maintain road sign, traffic signals, and road marking
  - Advise other agency/authorities to eradicate encroachments on roads to ensure smooth flow of traffic
- Standards for Road Design
  - Outline design standards of roads and convey concerned authorities for adopting while construction and repairing of roads
- Improvement/Development of Roads
- Transportation Surveys
  - Undertake traffic surveys and provide to the concerned authorities for formulating transport Policy
- Accident Data
  - Responsible for collection of accident data on basis of reports furnished by the police station monthly
- Identify the need for Pedestrian Facilities System of Public Transportation
  - Identify need and location of bus stops and terminals
- Plan and design system of public transportation in collaboration with concerned departments System of Freight Transport

- Parking Management
  - Advise concerned department where parking should be allowed or prohibited
  - Impose a fee for parking and device parking policy
- Traffic Impact Assessment
- Traffic Safety Education
- Traffic Police
  - Advise government regarding the improvement of Traffic Police
- Transportation Research

(TEPA, 2018)

5.6 Period 4: Second Democratic Era 1988-1999

The democratic history of Pakistan between 1988-1999 is undermined many times due to political revelers. In order to strengthen the democratic process general elections were held in 1988. Pakistan People's Party (PPP) with height national assembly seats formed their government with a coalition of other small parties. Mrs. Benazir Bhutto became the Prime Minister of Pakistan (NAP, 2020). In Punjab, Mr. Nawaz Sharif got elected as Chief Minister. However, the escalation of bitterness between national and provincial governments results in the collapse of the economy which ultimately lead to the dismissal of Benazir Bhutto's administration in 1990 (Nasr, 1994).
The next general elections were held in 1990 and Mr. Nawaz Sharif took oath as Prime Minister of Pakistan (NAP, 2020). However, this assembly could not complete its term resulting in the tenth general elections. In these elections, PPP claimed the majority of the seats and appointed Mrs. Benazir Bhutto as Prime Minister again for five years (NAP, 2020; Wynbrandt, 2009). However, after three years, Mr. Nawaz Sharif was again elected as Prime Minister of Pakistan (NAP, 2020). In 1998 decision to perform a nuclear test resulted in the imposition of sanctions which stifled the country's economy. The economic conditions and Kashmir issue (Kargil Conflict) leads to ousting of Nawaz Sharif in 1999 and an emergency was imposed by General Pervez Musharraf (Wynbrandt, 2009).

In relation to urban development, a major expansion in Lahore was also observed during this area because of a flux of population, particularly in the Cantonment. Since the population growth rate in Lahore was declining compared to previous years still the population migration to the Cantonment area was higher (54%). Much of the urban population shifted away from the urban center sprawling into the metropolitan region. After the constitution of the Lahore Development Authority, a large number of housing schemes were also observed which was one of the main reasons for expansion in Lahore (NESPAK, 2004). Table 12 shows the number of colonies/housing schemes developed in Lahore during two decades (e.g. 1980-1900, 1990-2000). A comprehensive study was also executed during this period to manged the ever-growing demand for transport.

Table 12 Colonization and Urbanization in Lahore – *Source: (Zaman, 2012)*

Year of Establishment	Number of Colonies	Average Area (Kanal[1])
1980-1990	90	416.8
1990-2000	55	1006.2

[1] 1 KANAL = 4500 SQUARE FEET

5.6.1 Comprehensive Study on Transportation System in Lahore, 1991

Japan International Cooperation Agency (JICA) was hired by Traffic Engineering and Planning Agency (TEPA) and Lahore Development Authority (LDA) to prepare the master plan for the city of Lahore with the following objectives.

- To prepare a master plan for the year 2010 with a provision of intermediary action plans for the year-2000
- To prepare feasibility studies for particular infrastructure projects and mass transit system

(JICA, 1991)

In this study, modern planning techniques were used to analyses travel demand and evaluation of transport projects. Figure 44 shows the proposed projects in the transport master plan of 1991. In this master plan new roads, bridges, and flyovers were proposed along with one mass transit system (current Bus Rapid Transit route) and few bus priority areas.

5.7 Period 5. Proclamation of Emergency

After the emergency imposed by General Pervez Musharraf, it was expected that general elections would be held soon however, Musharraf refused to restore the National Assembly until 2002 (NAP, 2020; Wynbrandt, 2009). The foremost important development during Musharraf's regime was the promulgation of the Local Government Ordinance 2001. Under this ordinance, the power was distributed to the local government level. Previously, an integrated local government system was absent. In urban areas town committees, municipal committees, and metropolitan/municipal corporations were established. The twelfth general elections were held in 2002, and General Pervez Musharraf retains the office of President of Pakistan for another 5 years (NAP, 2020).

During this period important steps were taken to control and guide urban development in Lahore. Therewith, an integrated master plan of Lahore was approved. Moreover, a plan was prepared for the development of rapid mass transit systems.

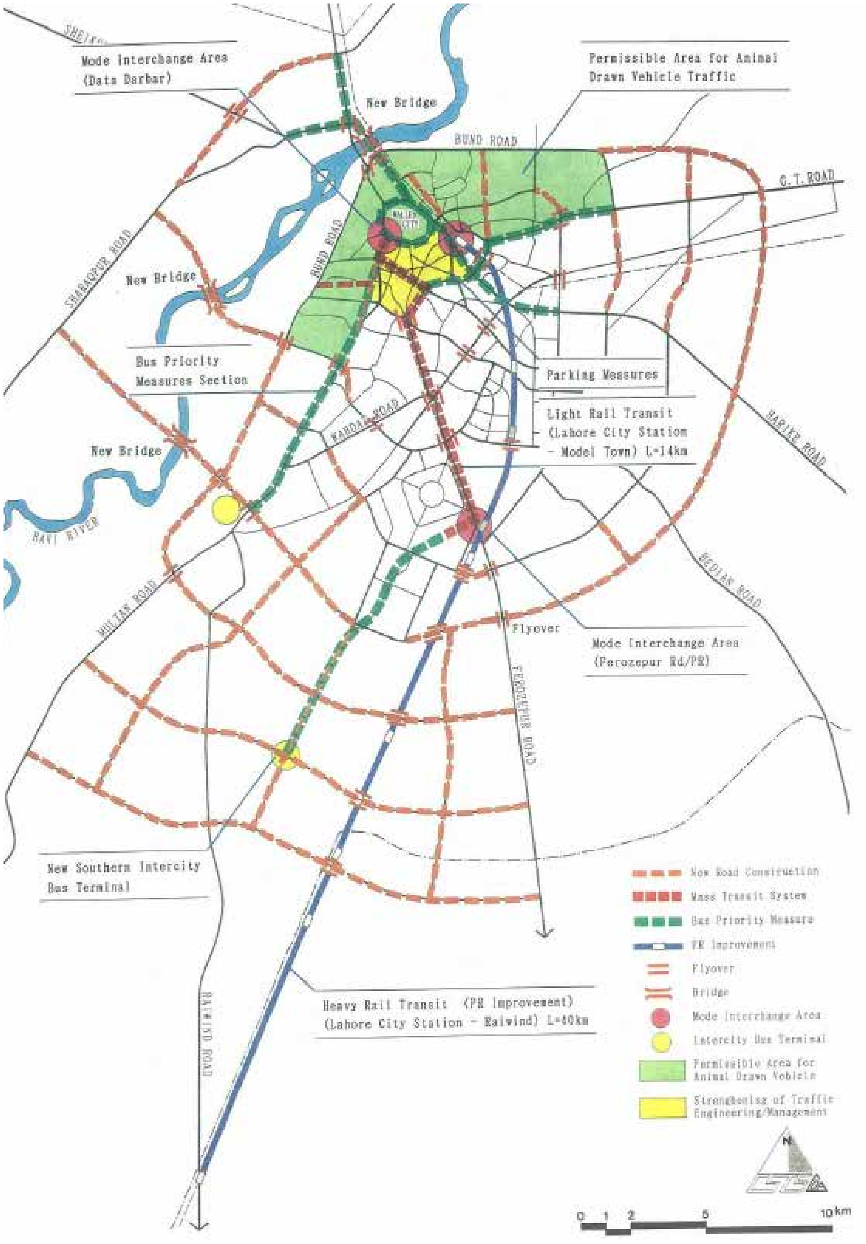


Figure 44 Comprehensive Study on Transportation System in Lahore-1991 – *Source: (JICA, 2012)*

5.7.1 Integrated Master Plan for Lahore

The third master plan for urban development in Lahore was approved in 2004 and was regarded as the Integrated Master Plan for Lahore (IMPL). The plan was envisioned to integrate urban development and transport planning. The plan again proposed an ongoing development in the south and south-west (see Figure 45). The study is presumed to be a comprehensive study in terms of urban planning however this study fails to forecast the urban development impacts on travel demand and future transport infrastructure requirements (JICA, 2012). Therefore, integration restrains this master plan to be entitled as IMPL in the full sense.

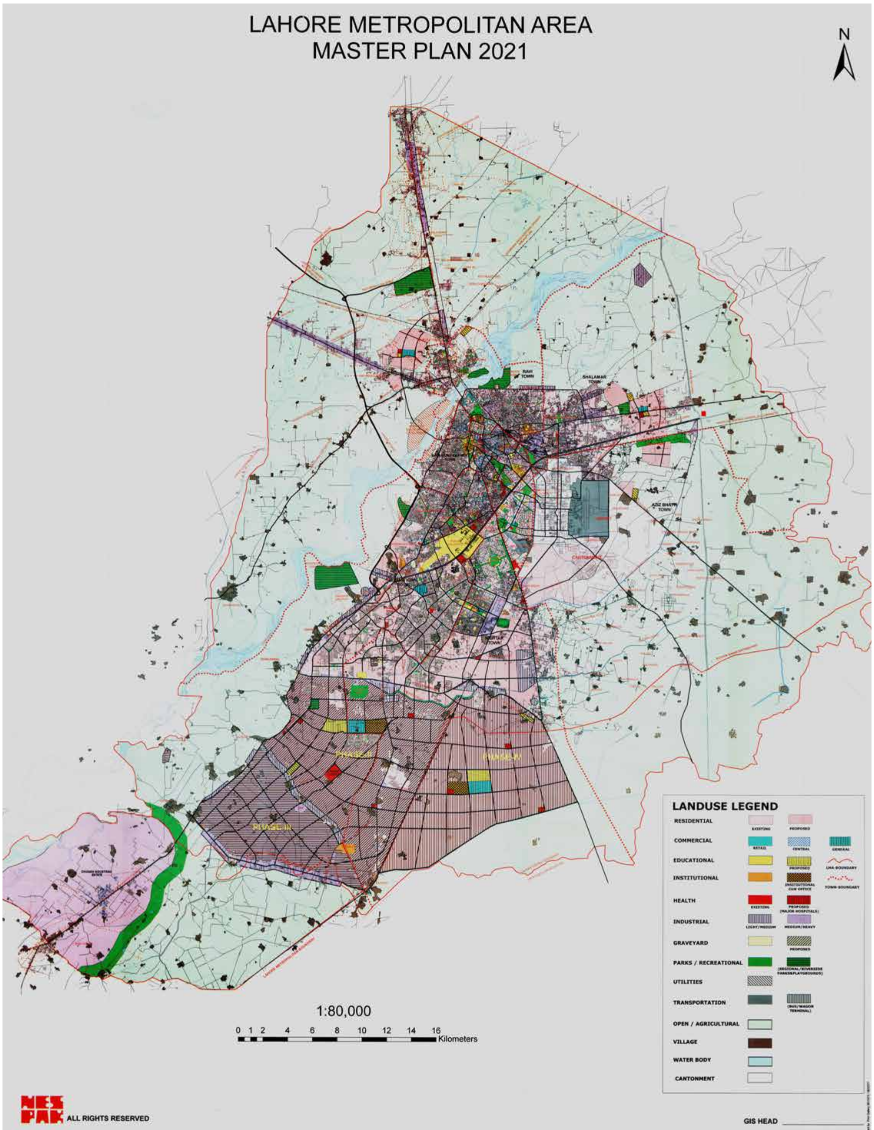


Figure 45 Integrated Master Plan for Lahore – *Source: (LDA, 2020)*

5.7.2 Lahore Rapid Mass Transit System (LRMTS)

The mass transit system proposed in 1991 could not be realized due to financial problems and weak political support. Therefore, in 2004 Government of Punjab launched Lahore Rapid Mass Transit System (LRMTS). The name clearly indicates that plan was envisioned to implement rapid mass transit systems in Lahore. This study was completed in 2006 and proposed four rail base mass transit lines as shown in Figure 46.

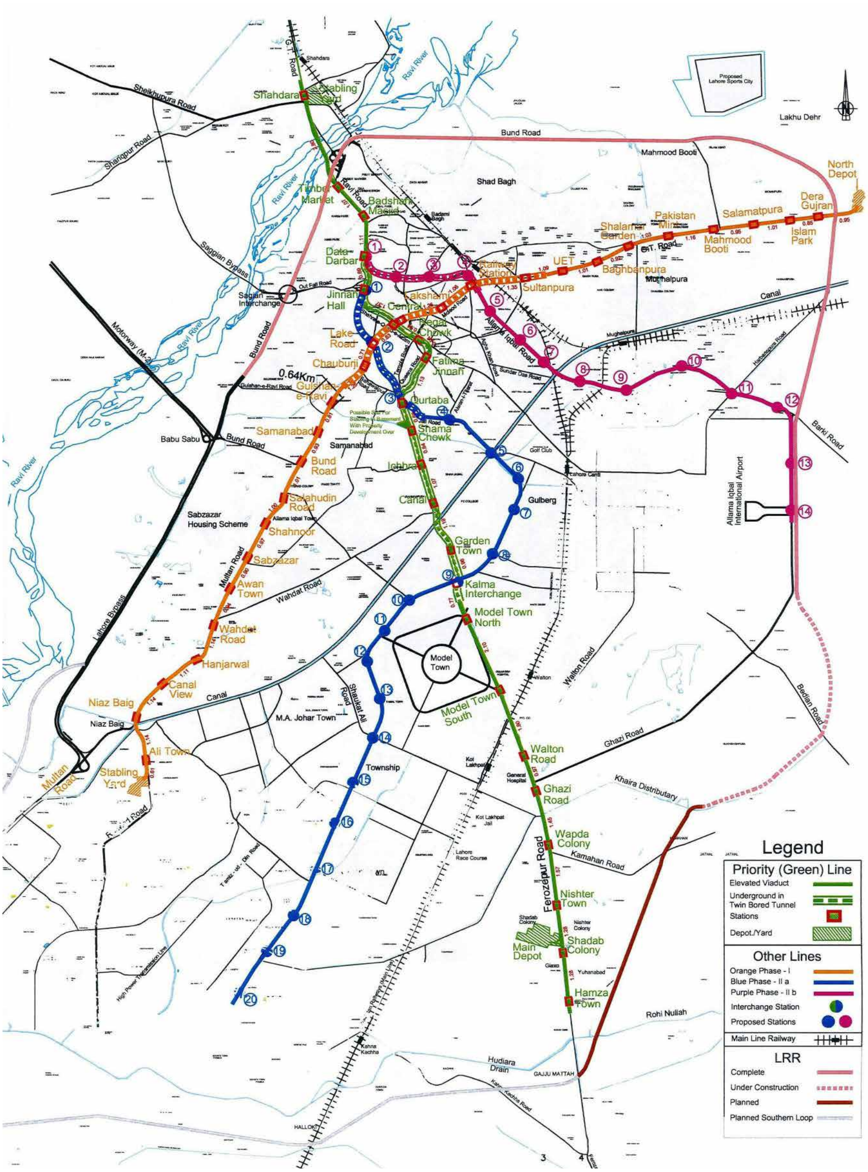


Figure 46 Lahore Rapid Mass Transit System – *Source: (JICA, 2012)*

5.8 Period 6. Final Democractic Era

In 2007 national assembly completed its tenure and General Pervez Musharraf announces the election for the year 2008 (NAP, 2020). Before the elections, there was an important setback for democracy when Benazir Bhutto was assassinated on 27 December 2007 (Wynbrandt, 2009). However, her party (Pakistan People's Party) managed to win the elections and Yousaf Raza Gillani was appointed as Prime Minister. (NAP, 2020). In Punjab, Pakistan Muslim League-N established their government. During this tenure (2008-2013) Chief Minister, Punjab (Mr. Shahbaz Sharif) proposed a transport study (JICA, 2012) for Lahore which leads to the implementation of the first mass transit system in 2013 (as BRT) (PMA, 2020). Along with these developments, different transport-related organizations/companies were also established in Lahore.

The next general elections were witnessed in 2013 and Pakistan Muslim League-N (PMLN) established their government with Mr. Nawaz Sharif as Prime Minister. During the PMLN government in Punjab prime focus was on transport development. Projects like Bus Rapid Transit in Lahore, and Rawalpindi, Lahore ring road (Southern loop) were implemented. One of the first-ever metro rail transit projects in Lahore was also initiated.

In terms of housing and urban development, a low-income housing scheme with the name of Aashiana-e-Quaid housing scheme was built for low-income people.
The list of projects initiated by the PML-N government in Lahore in the last 10 years is given below:

- Bus Rapid Transit (Green line) 2013
- Metro Rail Transit (Orange line)
- Ring Road Southern Loop 2016
- Signal free corridor (underpass and road construction) at Shoukat Ali Road
- Signal free corridor (Underpass and overhead bridge) at Jail road
- DHA Lahore Signal free corridor
- Azadi Chowk Interchange
- Beijing Underpass

Concerning urban development in Lahore, the jurisdiction of the Lahore Development Authority (LDA) was extended to the whole Lahore Division under LDA Master Plan Rules, 2014 which create the immediate necessity for a new master plan for the entire division. Lahore division includes districts of Lahore, Sheikhupura, Nankana Sahib, Kasur. The change in the jurisdiction of LDA is shown in Figure 47. During this government, Punjab Local Government Ordinance 2001 was amended and passed by the provincial government as Punjab Local Government Act in 2013.

However, the government initiated all these projects by borrowing money from other countries (for example metro rail transit in Lahore recently completed was implemented on a loan given by the Chinese government). As a result, the country goes into a high debt situation. The year 2017, was the end of the third tenure of Mr. Nawaz Sharif as Prime Minister. The corruption charges on the ruling party added to the situation and a paradigm shift from two-party politics was observed when Pakistan Tehreek-e-Insaf (PTI) come into force in 2018. Mr. Imran Khan was elected as Prime Minister of Pakistan. The present government has the vision to strengthen the national economy, give jobs to the unemployed, and build housing for poor people. The government has introduced a new policy to preserve the prime agricultural land around Lahore and promote high-rise development inside the city. In course of this local authorities (LDA) have also prepared new land-use rules (2020) and building and zoning regulations (2019) (see chapter 8 for more details). As the master plan of the city will expire in 2021 so, authorities are also in the process to start the preparation of the new urban development plan.

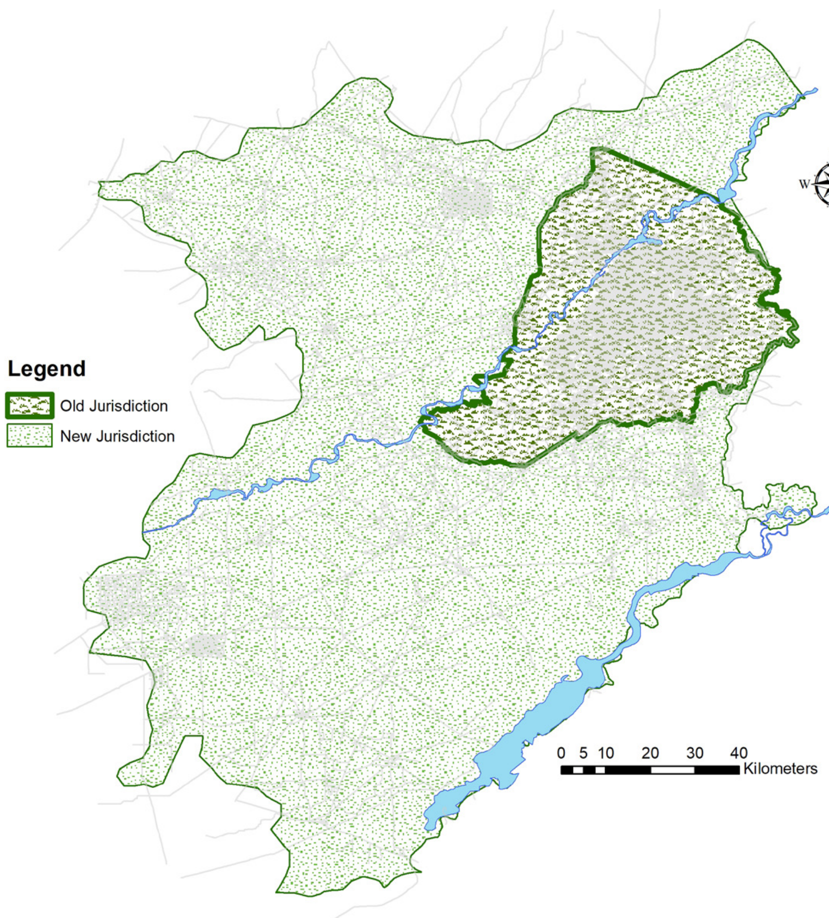


Figure 47 Old and New Jurisdiction of LDA

5.8.1 Lahore Transport Company (LTC)

Lahore Transport Company (LTC) is a regulatory body established in 2009 with a mission to provide safe, affordable, efficient, and environmentally friendly public transportation in Lahore. LTC is responsible to review and evaluate public transport routes, bus operation, improvement in public transport, and planning of new bus routes. LTC give permits to informal transport operator for specific routes. Currently, 13 high occupancy vehicles (HOV) and 33 Light occupancy vehicles (LOV) routes are operational in Lahore. LTC facilitates various private bus operators to meet the raising mobility need. LTC also takes part in infrastructure development like installation of shelters and flag posts etc. E-ticketing and cashless transactions are the initiatives taken by LTC. The first smartphone app "Apni Sawari" for real-time information about public transport is also launched by LTC (LTC, 2018).

5.8.2 Transport Planning Unit (TPU)

In March 2011, Transport Planning Unit (TPU) was established under the transport department to provide sustainable solutions for efficient management of infrastructure and transportation systems in the province. In 2011, it was decided that a new comprehensive transportation plan will be prepared for Lahore. Moreover, it was decided that JICA (Japan international cooperation agency) will work in coordination with TPU (TPU, 2020).

5.8.3 Lahore Urban Transport Master Plan-2030

In 2012, a new master plan was prepared with the name of the Lahore Urban Transport Master Plan (LUTMP). In this master plan, one amendment in LRMTS was proposed. In this amendment, one rail line which was proposed in LRMTS was replaced by a Bus Rapid Transit (BRT) line along with the addition of four new BRT lines as shown in Figure 48. In March 2012, the Government of Punjab (GoPb) decided to implement one of the proposed projects so the green line was selected. This route was proposed for a rapid mass transit system in all three transport plans and was having high travel demand. However, due to fund constraints, it was decided that the green line will be constructed on loan from Turkey and it would be implemented as bus rapid transit (locally named as metro) instead of a rail-based system. The construction of this project got completed in 2013. After the completion of BRT, the government decided to implement the orange line as a metro train. The construction of the orange line started in 2015. The Orange line started its operation on 25^{th} October 2020. This project is a part of the China Pakistan Economic Corridor (CPEC) and financed by both Government of Pakistan and China.

Figure 48 Lahore Urban Transport Master Plan-2030 – *Source: (JICA, 2012)*

5.8.4 Amendment in Integrated Master Plan for Lahore

Amendment in the integrated master plan for Lahore (IMPL) was executed in two phases. In the first phase, the eastern side of Lahore was opened for development. In this amendment, prime agriculture land use was converted to the residential area as shown in Figure 49. This amendment was approved in 2015. The second phase of this amendment covers a wider area for planning. Under this amendment entire division is taken as a project area including Sheikhupura, Nankana Sahib, and Kasur (see Figure 50). This amendment is planned for 2035 with an estimated population of 50 million. In this amended master plan different project areas were identified for planning.

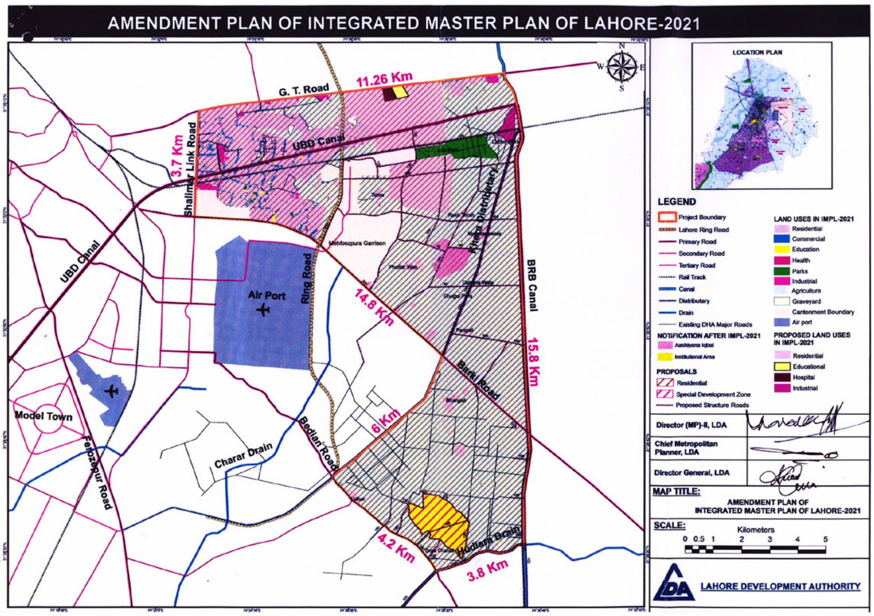


Figure 49 Amendment in Integrated Master Plan for Lahore Phase-I – *Source: (LDA, 2020)*

5.8.5 Punjab Mass Transit Authority (PMA)

Punjab Mass transit Authority (PMA) is a statutory body constituted in 2015 by the Government of Punjab intending to plan, design, construct, operate and maintain mass transit systems in major cities of the province Punjab. PMA's mission is to build and operate mass transit systems that are efficient, safe, and comfortable. It primarily focuses on planning, services contracting, and oversight of operations/contracts. PMA is particularly responsible for the development and maintenance of transit stations, corridors, depot, and other facilities as delineated by the government. Expansion of transit corridor, operation, and collection of fares is also the responsibility of PMA. All the expenditures for planning, designing, construction, maintenance, and operation of the mass transit system are incurred by PMA. Integration of public transport route also come into the jurisdiction of the authority. PMA can direct/restrict any other agency like LTC for issuing route permits along the corridor (PMA, 2020).

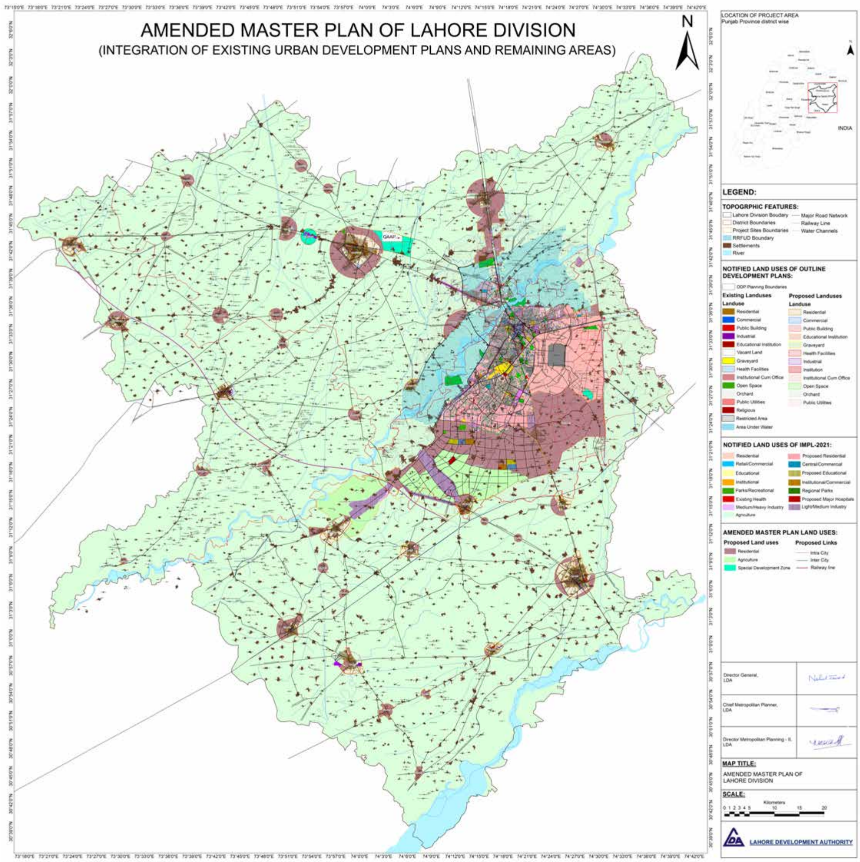


Figure 50 Amendment in Integrated Master Plan for Lahore Phase-II – *Source: Lahore Development Authority*

5.8.6 Punjab Provincial Transport Authority

Punjab provincial transport authority (PPTA) coordinates and controls the policies and activities of District Regional Transport Authorities. PPTA also issues permits for inter-district/interprovincial routes. Besides these following are the major function of PPTA:

- Checking of route permits issued by provinces for goods vehicles
- Authorize manufacturing and assemblage of rickshaws

5.9 Summary

This chapter discusses the different paradigms of urban governance in Pakistan particularly focusing on transportation and the urban development system in Lahore. Moreover, the role of various actors, institutions, and factors involved in transportation and urban development has also been explained in detail. The political history of Pakistan is quite awful that consists of military interferences. Moreover, political rivalries often undermind the fledgling democracy.

In the past several policies have been devised to control and guide the growth of the city. Since 1960, three transport studies and three master plans have been developed to solve the issues of transport and urban development. However, these institutions (policy documents) remain unsuccessful in integrating transport and urban development which results in the haphazard growth of the city. This is also because of the fact that are various agencies with a variety of responsibilities including urban growth management and infrastructure development. overlapping jurisdiction. Moreover, some of the actors (government agencies) have overlapping jurisdiction which further complicates the situation. For example, Lahore Development Authority (LDA) and Municipal Corporation are two agencies responsible for matters related to urban development. These agencies do not have clearly demarcated jurisdiction thus perform similar tasks in overlapping jurisdiction. Similarly, at present, almost ten different agencies performing duties related to transport planning, operation, and management. The involvement of various agencies, their overlapping role, and jurisdiction has made the situation of transport and urban development more complicated. Moreover, there exists poor coordination between these agencies. Therefore, there is a need to revamp the role of these agencies with clearly demarcated jurisdiction. There is also a need to enhance the coordination between these agencies for the integration of transport and urban development that will pave the way for sustainable urban development.

6

Travel Behavior Transition

6.1 Introduction

This chapter evaluates the transition in travel behavior succeeding the development of BRT. It begins with a description of variables related to travel behavior change. The first section elaborates the modal split and modal shift to BRT from 2012 to 2019. A binary logistic regression is applied to identify the factors affecting this modal shift, along with the extent to which each factor contributes toward this modal shift. Performance analysis further highlighted the main change in travel time and cost for different travel modes.

6.2 Modal Split

It is important to mention here that in Lahore the average number of daily riders (e.g. over 133,000) who use BRT is more than those in developed cities like Amsterdam (40,000) and Adelaide (32,000), as well as in developing cities like Ahmedabad (130,000) (BRTdata.org, 2020). This indicates significant numbers we are dealing with. If we compare the daily ridership of the BRT system in Asia, the BRT system of Lahore stands at the 15th position amongst the 44 in Asia (BRTdata.org, 2020). Figure 51 shows the boarding at each station of BRT per day. The highest boarding is detected at the terminal stations (i.e. Shahdhara and Gajjumata). This shows that BRT has successfully connected the outer fringes with central areas of the city. A more detailed station-wise modal split is presented in Figure 52. It is clear from the graph that after BRT, the motorcycle is the most used mode of transport, followed by walking. However, walking as a mode of travel is prominent also, especially around the Katachri and Azadi Chowk station.

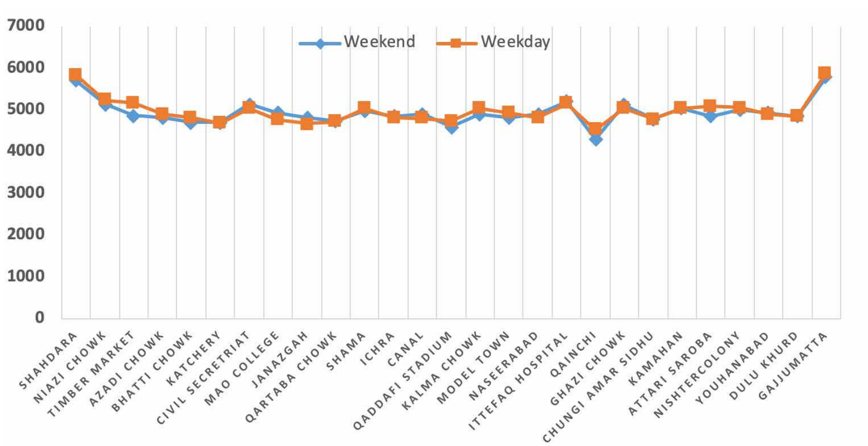


Figure 51 Station-wise BRT ridership

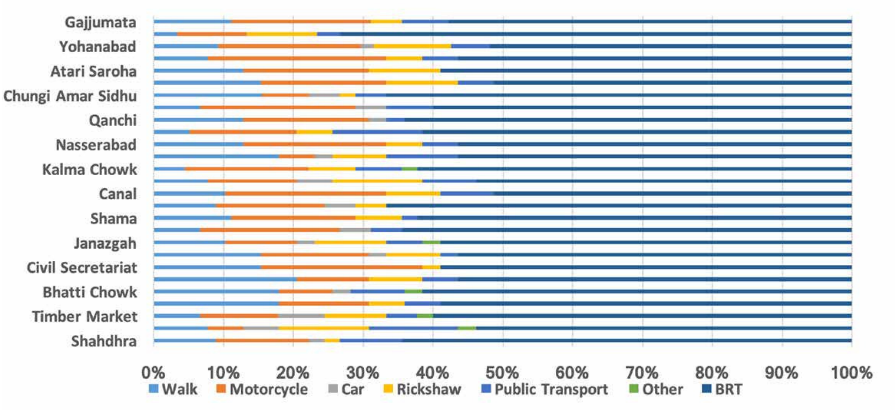


Figure 52 Station-wise Modal Split

6.3 Modal Shift

Figure 53 further elaborates on the modal shift to BRT between 2012 and 2019. There is a decline in the use of motorcycles, cars, and rickshaws. The use of motorcycles has declined from 28.5% to 15.5%. The field surveys indicated that overall car use has dipped from 23.1% to 2%. Such trends have also been observed in the US where a decline of 30% in private vehicle use was evident after the implementation of BRT (Cervero, 2013a). When comparing it with the whole of Lahore there has also been a decline in motor vehicle registration between 2016-2018. Similarly, rickshaw use has plummeted from 14.3% to 6.1%. Walking as a mode of transport has increased from 8.2% to 11.1%. Overall, findings illustrate that there is a modal shift towards more sustainable modes of transport, like walking and BRT.

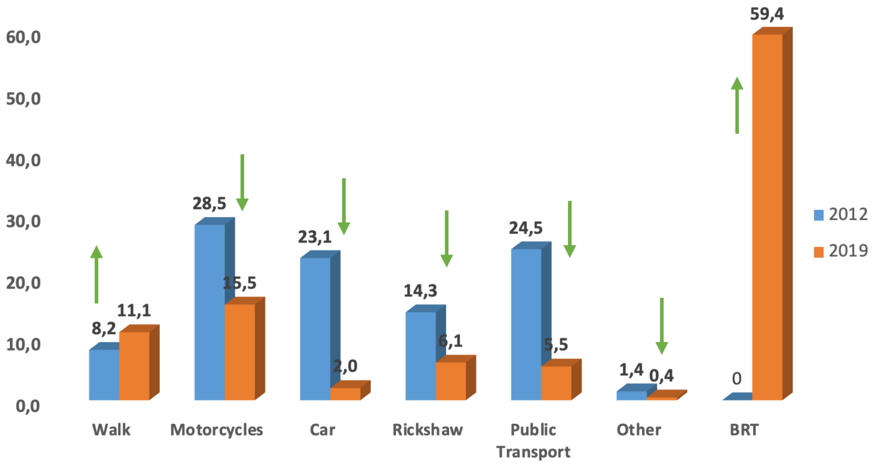


Figure 53 Model Shift 2012-2019

The mode shift for other public transport systems (such as buses and wagons, etc.) has also dropped due to restricted public transport services along the route, after the development of BRT. New routes were designed for public transport and feeder bus services. However, there has not been any change in the choice of private modes/ informal modes as no restrictions were imposed on the use of a private vehicle. This high travel shift to BRT might be due to the congestion along the BRT corridor. Similar trends were observed in Guangzhou, China where it becomes difficult to drive along the BRT corridor after implementation of BRT (Salon et al., 2014). Figure 54 shows the percentage of travelers shifting to BRT from other modes of transport. The travelers (8.2%) who walked before, 25.3% have shifted to BRT i.e. 2.07% of the total population. Similarly, 58.4% of motorcycle users have changed their mode of transport to BRT i.e. 16.62% of the total population. Out of 23.1% of car users, 44.7% have changed their mode to BRT i.e. 10.33% of the total population. Likewise, a mode shift to BRT (82.4%) has also been observed for rickshaw users i.e. 11.77% of total persons surveyed. From 24.5% of individuals who were traveling by other public transport services, 71.8% of respondents have shifted to BRT i.e. 17.61% of the entire population. Moreover, 68.80% of individuals using other modes like cycling have also shifted to BRT i.e. 0.99% of total people surveyed. The mode shift between other modes of transport has been explained in Table 13. It can be seen from the table that 9.5% of the motorcycle users have shifted to walking similarly 7.4% of car users have also changed their mode to walking. Likewise shift between other modes of transport is also apparent as 20.6% of car users are now using the motorcycle as their mode of transport.

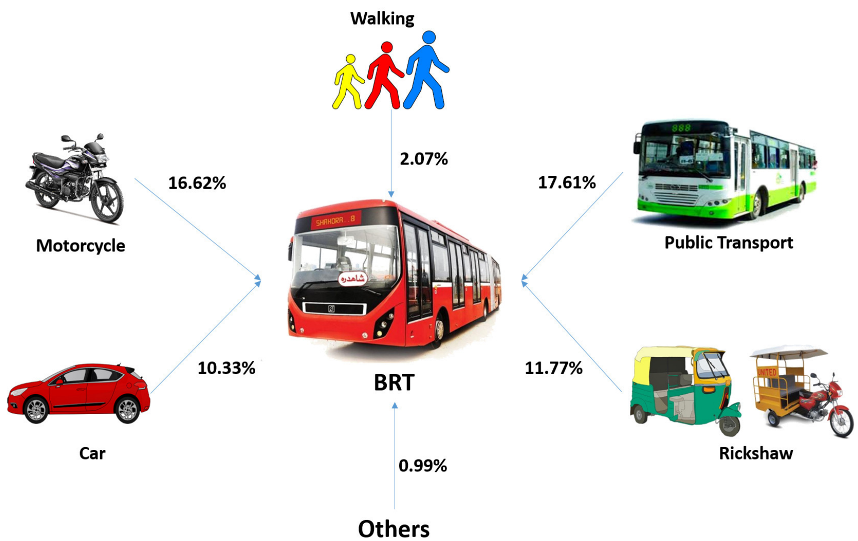


Figure 54 Mode Shift to BRT

Table 13 Modal shift between modes of transport

		Current mode of transport						
		Walking	Motorcycle	Car	Rickshaw	Public Transport	Other	BRT
Previous mode of Transport	Walking	51 (56%)	3 (3.3%)	1 (1.1%)	8 (8.8%)	5 (5.5%)	0 (0%)	23 (25.3%)
	Motor-cycles	30 (9.5%)	87 (27.4%)	5 (1.6%)	8 (2.5%)	2 (0.6%)	0 (0%)	185 (58.4%)
	Car	19 (7.4%)	53 (20.6%)	8 (3.1%)	33 (12.8%)	24 (9.3%)	5 (1.9%)	115 (44.7%)
	Rickshaw	5 (3.1%)	5 (3.1%)	0 (0%)	12 (7.5%)	6 (3.8%)	0 (0%)	131 (82.4%)
	Public Transport	16 (5.9%)	24 (8.8%)	8 (2.9%)	7 (2.6%)	22 (8.1%)	0 (0%)	196 (71.8%)
	Other	2 (12.5%)	1 (6.3%)	0 (0%)	0 (0%)	2 (12.5%)	0 (0%)	11 (68.8%)

6.4 Descriptive Statistics and Model Results

Descriptive statistics for the variables used for the binary logistic regression analysis are presented in Table 14. The category, number, and percentage of each explanatory variable are given in the table. Explanatory variables include mode of transport, travel frequency, respondent type, age, occupation, gender, education, household income, vehicle ownership, trip purpose. There are 59.4% of respondents who use bus rapid transit in Lahore and motorcycle is the second highest used mode of transport (15.5%). Table 15 gives information regarding continuous explanatory variables, including an increase/decrease in travel time and travel cost. A negative sign indicates a decrease in travel time and travel costs.

Table 14 Descriptive Statistics for categorical Explanatory Variables

Explanatory Variable	Category	N	Percentage
Mode of Transport	BRT	661	59.4
	Walking	123	11.1
	Motorcycle	173	15.5
	Car	22	2.0
	Rickshaw	68	6.1
	Public Transport	61	5.5
	Other	5	.4
Travel Frequency	Daily	766	68.8
	2-3 times a week	152	13.7
	Once a week	110	9.9
	Once a Month	85	7.6
Age	Below 18 years	199	17.9
	18-30 years	473	42.5
	31-45 years	290	26.1
	46-65 years	137	12.3
	Above 65 years	14	1.3
Occupation	Govt.-Employees	138	12.4
	Self-Employed/Businessmen	107	9.6
	Worker	562	50.5
	Student	242	21.7
	Other	64	5.8
Gender	Male	1038	93.3
	Female	75	6.74
Education	Uneducated	96	8.6
	Matric	293	26.3
	Intermediate	422	37.9
	Graduate	189	17
	Postgraduate	31	2.8
	Other	82	7.4
Household Income	Less than $64.69	292	26.23
	$64.70-$194.06	215	19.32
	$194.07-$388.11	320	28.75
	$388.12-646.85	231	20.75
	Above $646.85	55	4.94
Vehicle Ownership	Yes	459	41.2
	No	654	58.8
Trip Purpose	Commuting (Home/work)	748	67.2
	Leisure	15	1.3
	Education	206	18.5
	Shopping	65	5.8
	Other	79	7.1

Table 15 Descriptive Statistics for continues Explanatory Variables

Variables	Units	Mean	S.D
Increase/decrease in travel time	Minutes	-13.55	15.96
Increase/decrease in travel cost	$/month	-1.17	2.06

6.4.1 Model-1 Binary logistic regression

Discrete choice models are used to identify the choices of individuals among different alternatives. These models were established based on the idea of utility maximization, inferring that an individual chooses a mode devising maximum utility (Ben-Akiva & Bierlaire, 1999). The binary logistic model is applied where an individual had to choose between two options, whereas, for more than two discrete choices multinomial model is used. In this research association between the dependent variable (Y) and a set of independent variables (X) is investigated using binary logistic regression (Harrell Jr, 2015; Tranmer & Elliot, 2008). Binary logistic regression has been used widely when the dependent variable is dichotomy categorical (with responses 0 and 1) and the independent variables are categorical or continuous (Kepaptsoglou et al., 2020). Equation 1 represents the utility function for mode (BRT).

$$U_{BRT} = C + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 \ldots\ldots + \beta_i X_i \qquad \textbf{1}$$

Where:

UBRT = represent the utility function of mode "BRT"
C = Constant
βi = Coefficient (Weight of explanatory variable)
Xi = Independent/Explanatory variable correlated with the mode choice

In this research, mode choice for bus rapid transit (with options "Yes" or "No") served as a dependent variable, whereas income, education, occupation, age, gender, travel purpose, vehicle ownership, and reason to choose/not BRT are considered as explanatory variables. The response for dependent variables Y can be 0 or 1; with Y=1 indicating that an individual selected BRT as a mode of transport, whereas Y=0 shows that an individual did not choose BRT (see Table 16).

Table 16 Coding for Dependent Variable

Dependent Variable Encoding	Original Value	Internal Value
BRT Use	No	0
	Yes	1

The probability (P_{BRT}) that an individual would choose BRT as travel mode based on binary logistic regression is mathematically demonstrated by Equation 2, while the probability (Pn) that BRT would not be chosen; could be calculated using Equation 3.

$$P_{BRT} = e^{U}m \,/\, (1 + e^{U}m) \quad (2)$$

$$P_n = 1 - P_m \quad (3)$$

In binary logistic regression, yi which is the dependent variable represents the log of the ratio of the probability P_{BRT} to the probability $(1 – P_{BRT})$ (Kepaptsoglou et al., 2020). Thus, binary logistic regression takes the form as represented by mathematical expression in Equation 4.

$$log\left(\frac{P_{BRT}}{1 - P_{BRT}}\right) = \beta_0 + \beta_1 x_1 + \beta_2 x_1 + \ldots\ldots\ldots\ldots\ldots\ldots \beta_n x_n \quad (4)$$

Where P_{BRT} is the probability of selecting BRT as a mode of travel, βo is the intercept for the logistic regression, and β11 gives information about a certain characteristic of a trip along with its associated parameter estimate.

6.4.2 Model-2 Analysis of Variance (ANOVA)

An analysis of variance (ANOVA) test was performed to further compare the mean change in travel time and travel cost for different travel modes. Means of change in travel time and travel costs were compared for BRT, car, motorcycle, rickshaw, walking, public transport, and other modes of transport. An increase/decrease in travel time was taken as a dependent variable. For the second ANOVA run increase/decrease in travel cost was taken as a dependent variable.

6.5 Results and Discussion

6.5.1 Statistical Model Application

Table 17 presents the significance level and weights for each category of the explanatory variables. The statistics for log-likelihood, Nagelkerke R2, and Cox & Snell R2 are presented at the bottom of Table 17. The Nagelkerke R2 value for the model shows 69% of the data variation is covered by the model. The results of binary logistic regression reveal that trip purpose is significantly associated with the choice of Bus Rapid Transit (BRT). Trip purpose for commuting (home/work) (β = 5.780, p-value = 0.000), shopping (β = 5.148, p-value = 0.000), education (β = 4.745, p-value = 0.000) and leisure (β = 4.431, p-value = 0.003) are positively associated with the choice of BRT; at a significance level of 0.01 with reference to trips executed for other purposes. The probability to choose BRT as a mode of transport is highest when the trip purpose is commuting. For individuals below 18 years (β = 3.033, p-value = 0.002) and 18-30 years (β = 2.477, p-value = 0.003), BRT is a preferred mode of travel. The probability to choose BRT is highest for the age group below 18 years. As described earlier BRT is connected with important educational institutes and it's a convenient, fast, and cheaper transport option for individuals with age less than 18 years and are mostly students. Occupation is significantly related to the choice of BRT. Workers (β = 5.557, p-value = 0.000), government-employees (β = 5.044, p-value = 0.000), self-employed (β = 4.598, p-value = 0.000) and students (β = 3.145, p-value = 0.008) have more probability to choose BRT, compared to individuals having other occupations. From the range of occupations, workers are the ones with the maximum probability to choose BRT. The gender of an individual is significantly associated with the selection of BRT. The results of the analysis divulge compared to females. Males have more probability (β = 1.149, p-value = 0.002) to choose BRT to execute their trips. Sexual harassment can be one of the reasons that restrict females to choose public transport, as indicated by B. Z. Malik, ur Rehman, Khan, and Akram (2020). Similar trends were observed in Barranquilla, Colombia by Orozco-Fontalvo, Soto, Arévalo, and Oviedo-Trespalacios (2019).

Education significantly influences the choice of BRT. Individuals with no education/ uneducated (β = -1.530, p-value = 0.004) or having education as matric (β = -1.286, p-value = 0.005) or on an intermediate level (β = -1.254, p-value = 0.004) have less probability to choose BRT as a mode of transport. The negative sign indicates that individuals having matric or intermediate education have less probability to choose BRT as a mode of transport, compared to a person having higher or other educational levels. It is important to note that the increase in education also expands the probability to select BRT. Uneducated individuals have the least probability to take BRT as their mode of travel. Education has an important role to play, as BRT use increases with a higher level of education. Awareness campaigns among uneducated or less educated people can help to change their travel behavior as well.

Table 17 Model Estimates for binary logistic regression

Variables	B	Sig.
Travel purpose (Other) ref		
Travel purpose (Commuting Home/Work)	5.780	.000*
Travel purpose (Leisure)	4.431	.003*
Travel purpose (Education)	4.745	.000*
Travel purpose (Shopping)	5.148	.000*
Age (Above 65 years) ref		
Age (Below 18 years)	3.033	.002*
Age (18-30 years)	2.477	.003*
Age (31-45 years)	0.495	.545
Age (46-65 years)	-.522	.545
Occupation (Other) ref		
Occupation (Govt.-Employees)	5.044	.000*
Occupation (Self-Employed/Businessmen)	4.598	.000*
Occupation (Worker)	5.557	.000*
Occupation (Student)	3.145	.008*
Gender (Female) ref		
Gender (Male)	1.149	.002*
Education (Other) ref		

Education (Uneducated)	-1.530	.004*
Education (Matric)	-1.286	.005*
Education (Intermediate)	-1.254	.004*
Education (Graduate)	-0.080	.871
Education (Postgraduate)	0.964	.226
Household Income (Above $646.85) ref		
Household Income (Less than $64.69)	4.039	.000*
Household Income ($64.70-$194.06)	4.090	.000*
Household Income ($194.07-$388.11)	2.660	.000*
Household Income ($388.12-646.85)	2.341	.000*
Do you own private transport (No) ref		
Do you own private transport (Yes)	-2.227	.000*
Reason to choose/not BRT (Travel Cost)	2.651	.000*
Reason to choose/not BRT (Travel Time)	3.135	.000*
Reason to choose/not BRT (Comfort)	0.402	.433
Reason to choose/not BRT (Reliability)	1.287	.020
Reason to choose/not BRT (Safety)	1.978	.000*
Constant	-14.741	.000*

Number of Observation = 1,113
-2 Log Likelihood = 702.638
Nagelkerke R Square = 0.692

ref = reference category
* p‹0.01
Cox & Snell R Square = 0.513

Household income is also positively associated with the choice of BRT. The probability of travel by BRT is highest (β = 4.039, p-value = 0.000) for individuals having household income below $64.69. The probability is a bit higher (β = 4.090, p-value = 0.000) for individuals having income between $64.70-194.06. The probability to choose BRT for individuals with income $194.07-388.11 (β = 2.660, p-value = 0.000) and $388.12-646.85 (β = 2.341, p-value = 0.000) is higher compared to individuals having income more than $646.85, but is less when compared to other low income ranges. This indicates that BRT in Lahore is serving its purpose to provide a sustainable mode of transport to the urban poor. However, policy measures are also needed to change the travel patterns of high-income people and to shift them to more sustainable modes of transportation. Awareness campaigns, road pricing coupled with free BRT rides could help to change their travel choice. Vehicle ownership is negatively associated with the selection of BRT as a mode of transport. The individual without any type of personal vehicle has more probability (β = -2.227, p-value = 0.000) to choose BRT, compared to an individual having one. In general, vehicle ownership in cities like Lahore is growing at a rapid rate; so, the question remains how can we change the travel behavior of people with access to a private vehicle? In this situation policy measures, like restrictions on private vehicle use or congestion charging in the central area of the city, can induce a model shift to BRT.

The analysis of service-related attributes of BRT reveals that these are significantly associated with the choice of BRT. While analyzing the reason to choose or not to choose BRT, we can observe that travel time (β = 3.135, p-value = 0.000), travel cost (β = 2.651, p-value = 0.000), and safety (β = 1.978, p-value = 0.000) are significantly associated with the BRT choice. Travel time is the foremost probability to influence BRT selection. Travel time and travel costs are two important service attributes of BRT to influence the mode choice of people. Therefore, it is important to further investigate how a change in travel time and travel cost vary across different travel modes between 2012-2019.

6.5.2 Performance Analysis

One-way analysis of variance (ANOVA) is performed to compare the performance of different modes. Performance is measured through the change in travel time and travel cost for different travel modes. The ANOVA test indicates a significant difference in mean change in travel time [F (6.1106) = 194.43, p=0.000] between travel modes (see Table 18). Post hoc comparison is also performed using the Tukey test. The result of post hoc comparison indicates that there is a significant difference between the change in travel time for BRT and car (p=0.000) individuals using BRT have less travel time (average 22.50 minutes/trip) than those who are using a car as a mode of transport (see Table 19). A significant difference is also observed for change in travel time between BRT and other modes, such as motorcycle, rickshaw, walking, public transport (p=0.000), and others (p=0.001). People using BRT experience less travel time, compared to motorcycles (average 23.87 minutes/trip), rickshaw (average 23.15 minutes/trip), walking (average 22.96 minutes/trip), public transport (average 22.84 minutes/trip), and other modes of travel (average 20.00 minutes/trip). The ANOVA test for change in travel costs shows a significant difference in travel costs [F (6.1106) = 38.72, p=0.000] between various travel modes (see Table 20). Tukey test is used to perform the post-hoc comparison. There is a significant difference between the change in travel cost, for BRT and car (p=0.000), since individuals using BRT experience less travel cost (average $4.71/week-month), than those using a car as a mode of travel (see Table 21). Whereas, no significant difference is recorded for change in travel time between BRT and other modes such as motorcycle, rickshaw, public transport, and others.

Table 18 Test of Between Subjects Effects (travel time)

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	145463.838[a]	6	24243.973	194.428	.000
Intercept	2260.985	1	2260.985	18.132	.000
Transport mode	145463.838	6	24243.973	194.428	.000
Error	137911.123	1106	124.694		
Total	487856.000	1113			
Corrected Total	283374.961	1112			

a) R Squared = .513 (Adjusted R Squared = .511)

Table 19 Multiple Comparison (travel time)

(I) Current mode of transport	(J) Current mode of transport	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
BRT	Walking	-22.96*	1.097	.000	-26.20	-19.72
	Motorcycle	-23.87*	.954	.000	-26.69	-21.05
	Car	-22.50*	2.420	.000	-29.65	-15.35
	Rickshaw	-23.15*	1.422	.000	-27.35	-18.95
	Public Transport	-22.84*	1.494	.000	-27.25	-18.43
	Other	-20.00*	5.013	.001	-34.81	-5.20

*Tukey HSD (partial output)

Table 20 Test of Between Subjects Effects (travel cost)

	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	816.577[a]	6	136.096	38.715	.000
Intercept	155.411	1	155.411	44.210	.000
Transport mode	816.577	6	136.096	38.715	.000
Error	3887.932	1106	3.515		
Total	6216.628	1113			
Corrected Total	4704.510	1112			

a. R Squared = .174 (Adjusted R Squared = .169)

Table 21 Multiple Comparison (travel cost)

(I) Current mode of transport	(J) Current mode of transport	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
BRT	Walking	1.6002*	0.18411	.000	1.0564	2.1440
	Motorcycle	0.2329	0.16012	.772	-0.2400	0.7059
	Car	-4.7070*	0.40633	.000	-5.9072	-3.5068
	Rickshaw	0.1503	0.23878	.996	-0.5550	0.8555
	Public Transport	0.4747	0.25089	.486	-0.2664	1.2158
	Other	1.9745	0.84165	.223	-0.5116	4.4605

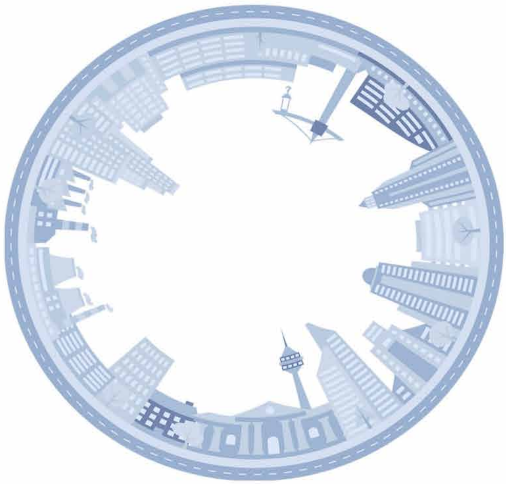
*Tukey HSD (partial output)

6.6 Summary

This chapter explores the travel behavior change implicated in Lahore by Bus Rapid Transit (BRT). A substantial modal shift has been observed toward BRT from other modes of transport. The empirical evidence from Lahore has shown that the operation of BRT has also enhanced the use of green mood of transport like walking. The investigation of factors affecting mode shift to BRT indicated that traveler's characteristics such as age, gender, occupation, education, and income significantly influence this mode shift. Furthermore, travel time, travel cost, and safety are the important service attributes of BRT that have an effect on mode choice behavior. Performance analysis has shown that BRT provides services with less travel time and cost compared to other modes of transport.

7

Urban Transformation



Part of this chapter have been previously published as:
Basheer, M. (2020). Application of an actor relational approach in Bus Rapid Transit-land use interaction.
In OPENING UP THE PLANNING LANDSCAPE (pp. 215-223). In Planning

7.1 Introduction

In the previous chapter, we have discussed the impacts of Bus Rapid Transit (BRT) on travel patterns. There are also externalities related to urban development induced by BRT investment. This chapter begins with the identification of land use transformation perceived after the development of BRT followed by categorization of impacts. Besides land use transformation, changes in urban development have also been mapped to answer the sub-question: What are the impacts of BRT on urban development? The opinion of different actors involved in urban development has been put forward to unveil the motives behind land use transformation, its interrelation with transport, and the economy.

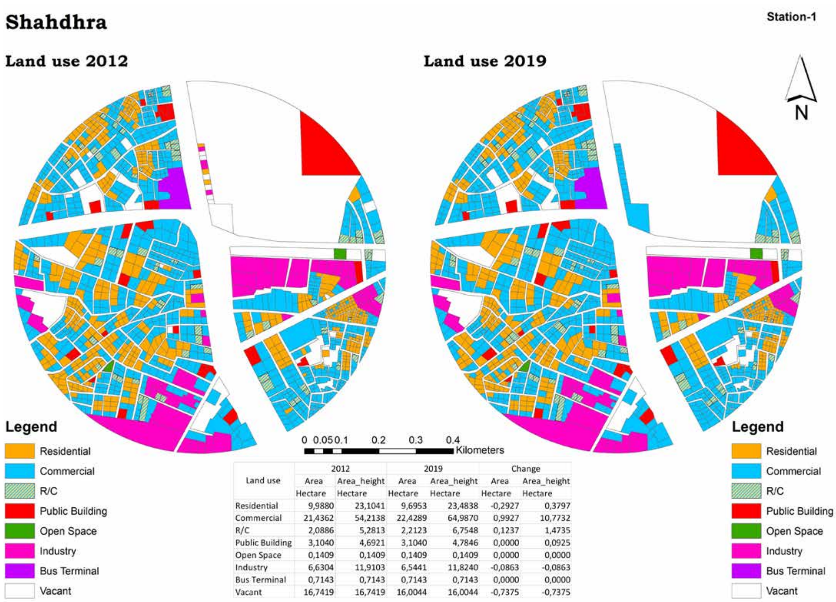
7.2 Land use Transformation

7.2.1 Station-1: Shahdara Station

Shahdara station is one of the terminals of BRT Lahore characterized by commercial and industrial activities. At this station, a significant increase in commercial activities after the operation of BRT is observed. This increase in land area for commercial use is recorded to be 0.99 hectares. These numbers even add up when the number of additional stories is taken into account. Including these, it makes the overall increase in land area under commercial use be 10.77 hectares during the period from 2012 to 2019. Figure 55 shows that the addition of a story is, by far, the prime activity around the station in terms of transformation, and only a few properties show land-use change and new development activities.

Figure 55 Land-use transformation at Shahdara station

Figure 56 shows there is indeed significant densification in the vicinity of Shahdara station. Moreover, there is also an increase in the covered area for residential and mixed-use with 0.38 and 1.47 hectares, respectively. Although this is not as much as compared to commercial use, still it signifies the multifunctional scope of the station area. On the other hand, industrial use shows a decline in its covered area. Despite the ongoing densification trend, as of the year 2019, there is still an around 16-hectare area laying vacant within a 500-meter buffer of BRT station. This indicates the station's potential for further development.



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	9,9880	23,1041	9,6953	23,4838	-0,2927	0,3797
Commercial	21,4362	54,2138	22,4289	64,9870	0,9927	10,7732
R/C	2,0886	5,2813	2,2123	6,7548	0,1237	1,4735
Public Building	3,1040	4,6921	3,1040	4,7846	0,0000	0,0925
Open Space	0,1409	0,1409	0,1409	0,1409	0,0000	0,0000
Industry	6,6304	11,9103	6,5441	11,8240	-0,0863	-0,0863
Bus Terminal	0,7143	0,7143	0,7143	0,7143	0,0000	0,0000
Vacant	16,7419	16,7419	16,0044	16,0044	-0,7375	-0,7375

Figure 56 Shahdara land-use 2012, 2019

7.2.2 Station-2: Timber Market

Timber Market station area is characterized by dense residential and commercial activities. The timber market is in close vicinity to the historical landmarks of Lahore (e.g., Greater Iqbal Park, Lahore Fort, and Badshahi Mosque). As compared to Shahdara station, few land-use changes are observed around Timber Market station. A total of 2.43-hectare area is being converted to commercial use, besides an evident mixed land-use transformation (Figure 57).

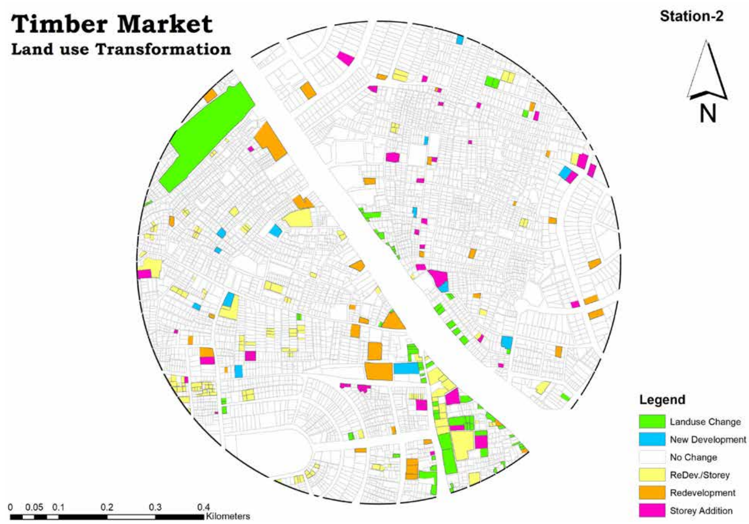
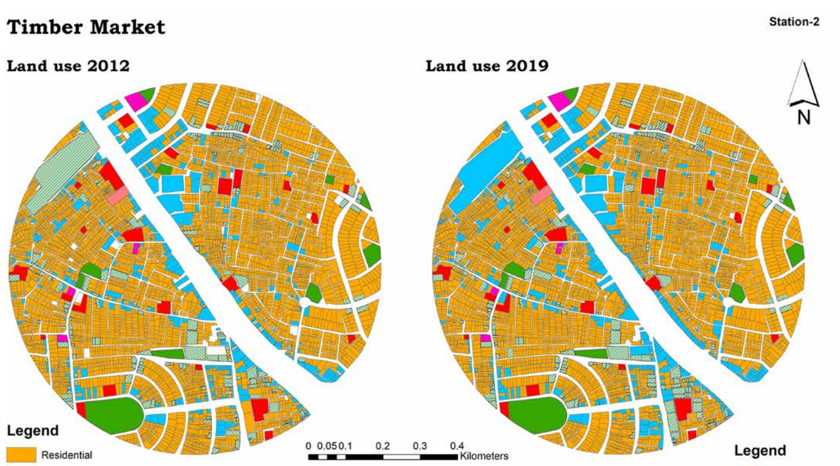


Figure 57 Land-use transformation at Timber Market station

The station area shows a minor increase in commercial activities, whereas residential and residential/commercial areas are declining (see Figure 58). However, an increase in the height of buildings of commercial use is evident in this area.



Land use	2012		2019		Change	
	Area	Area_Height	Area	Area_Height	Area	Area_Height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	41,0087	78,1679	40,5474	77,9215	-0,4613	-0,2464
Commercial	6,4423	11,2651	8,8761	19,2211	2,4338	7,9560
R/C	5,7849	13,6427	4,3002	10,5336	-1,4847	-3,1091
Public Building	2,1827	3,9384	2,1827	4,7575	0,0000	0,8191
Open Space	2,2677	2,2677	2,2677	2,2677	0,0000	0,0000
Hospital	0,1616	0,1616	0,1616	0,1616	0,0000	0,0000
Industry	0,3297	0,3710	0,3297	0,3710	0,0000	0,0000
Vacant	0,4879	0,4879	0,0000	0,0000	-0,4879	-0,4879

Figure 58 Timber market land-use 2012, 2019

7.2.3 Station-3: Qartaba Chowk

Qartaba Chowk serves as a hub of commercial activities and provides links to important places and commercial centers in Lahore. Similar to Timber Market station, Qartaba Chowk entails different types of land-use transformation. Although major commercial developments occurred on the southern side. On the other hand, hardly any story addition is observed over here (see Figure 59).

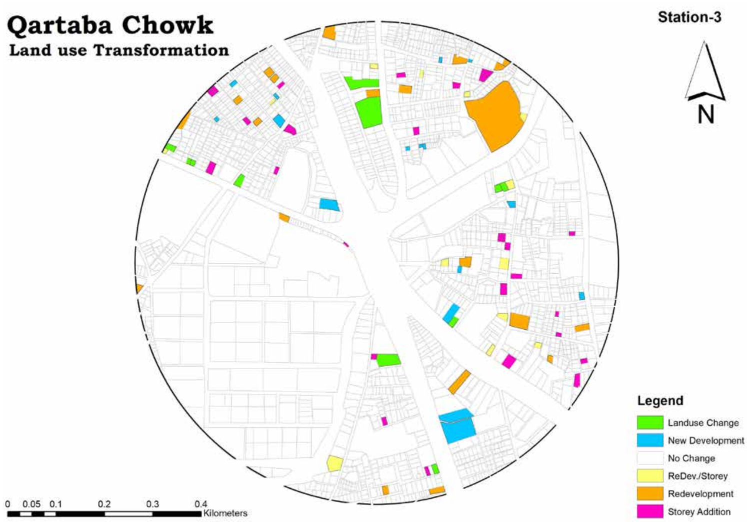
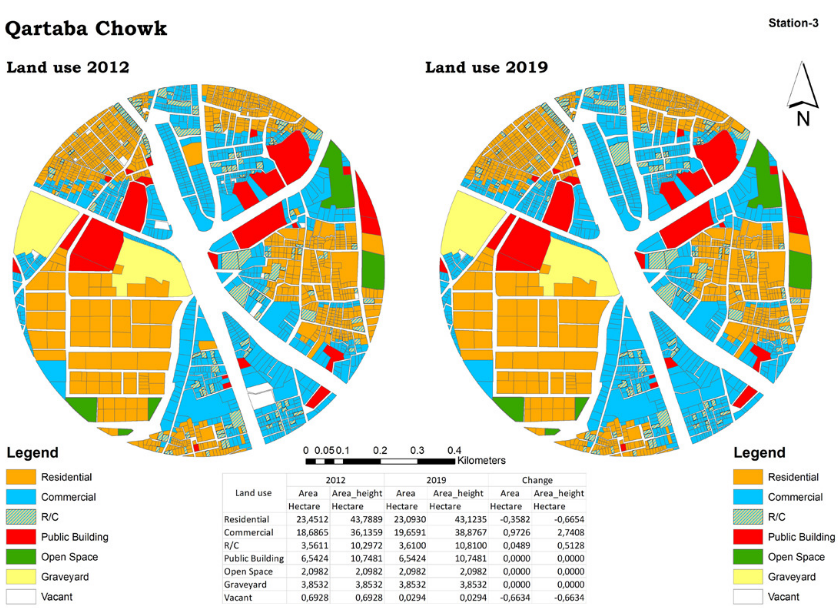


Figure 59 Land-use transformation at Qartaba Chowk station



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	23,4512	43,7889	23,0930	43,1235	-0,3582	-0,6654
Commercial	18,6865	36,1359	19,6591	38,8767	0,9726	2,7408
R/C	3,5611	10,2972	3,6100	10,8100	0,0489	0,5128
Public Building	6,5424	10,7481	6,5424	10,7481	0,0000	0,0000
Open Space	2,0982	2,0982	2,0982	2,0982	0,0000	0,0000
Graveyard	3,8532	3,8532	3,8532	3,8532	0,0000	0,0000
Vacant	0,6928	0,6928	0,0294	0,0294	-0,6634	-0,6634

Figure 60 Qartaba Chowk land-use 2012, 2019

The land-use map of 2012 shows very limited potential for new development in the form of available vacant land. However, we discovered a conversion from residential to commercial and residential/commercial activities during the studied period. This conversion adds 2.74 hectares and a 0.51-hectare area to commercial and residential/ commercial use, respectively, when compared to 2012 (see Figure 60).

7.2.4 Station-4: Shama Chowk

Mixed-use development is witnessed around Shama Chowk station. Residential uses are growing but mainly by the increase in building heights. Figure 61 illustrates that change in building height is the major transformation observed around Shama Chowk station.

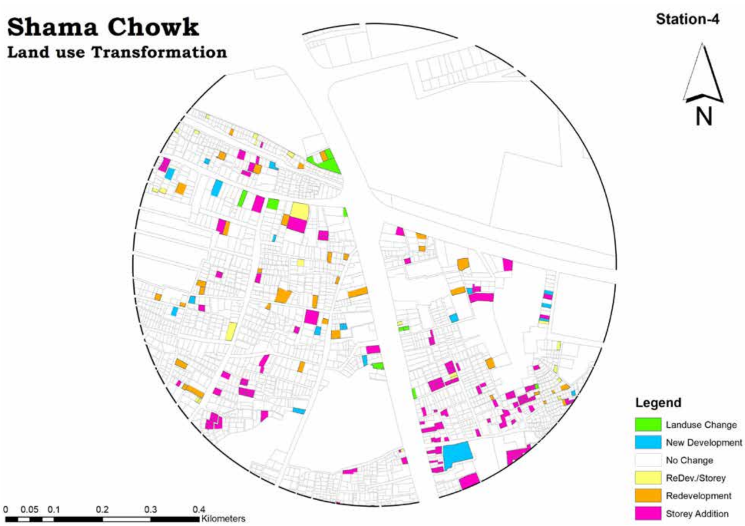
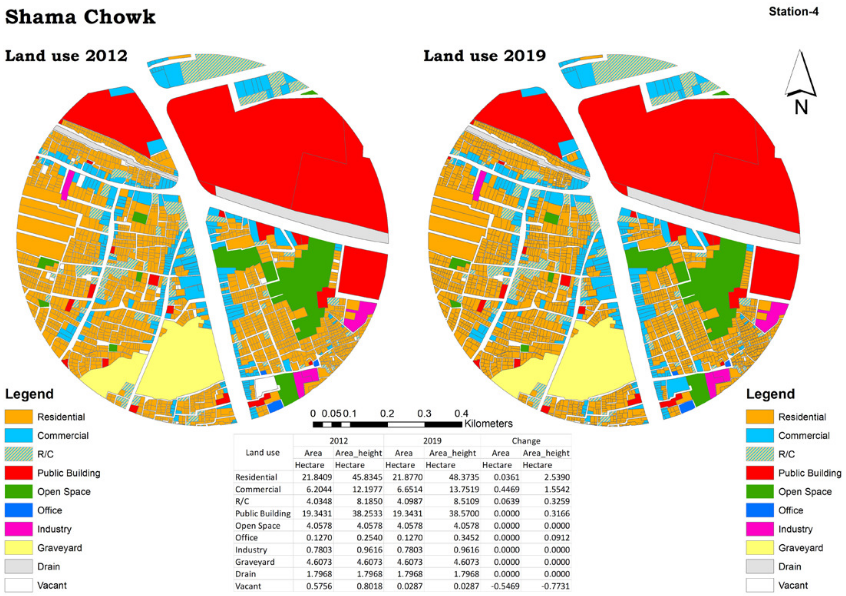


Figure 61 Land-use transformation at Shama Chowk station

The change in land coverage for residential use is less than 0.04 hectares. However, the land-use conversion is more prominent for commercial use, with an evident increase of 0.45 hectares (see Figure 62). Moreover, commercial use is also showing an increase in building heights.



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	21.8409	45.8345	21.8770	48.3735	0.0361	2.5390
Commercial	6.2044	12.1977	6.6514	13.7519	0.4469	1.5542
R/C	4.0348	8.1850	4.0987	8.5109	0.0639	0.3259
Public Building	19.3431	38.2533	19.3431	38.5700	0.0000	0.3166
Open Space	4.0578	4.0578	4.0578	4.0578	0.0000	0.0000
Office	0.1270	0.2540	0.1270	0.3452	0.0000	0.0912
Industry	0.7803	0.9616	0.7803	0.9616	0.0000	0.0000
Graveyard	4.6073	4.6073	4.6073	4.6073	0.0000	0.0000
Drain	1.7968	1.7968	1.7968	1.7968	0.0000	0.0000
Vacant	0.5756	0.8018	0.0287	0.0287	-0.5469	-0.7731

Figure 62 Shama Chowk land-use 2012, 2019

7.2.5 Station-5: Ichra

Ichra is a famous area of Lahore for its retail and can be characterized by its commercial and residential/commercial activities. Land area for residential use is declining as a result of conversion to commercial or residential/commercial use. However, a positive change is recorded in the heights of residential buildings. Similarly, commercial and residential/commercial use density is also increasing. Overall, we

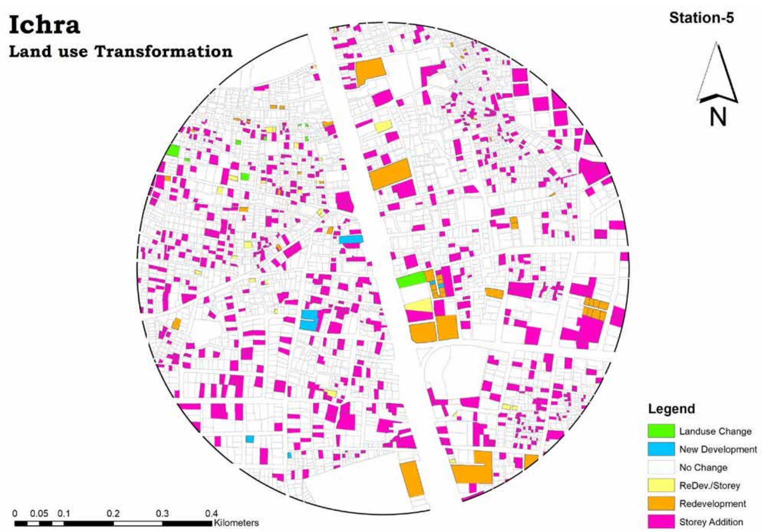
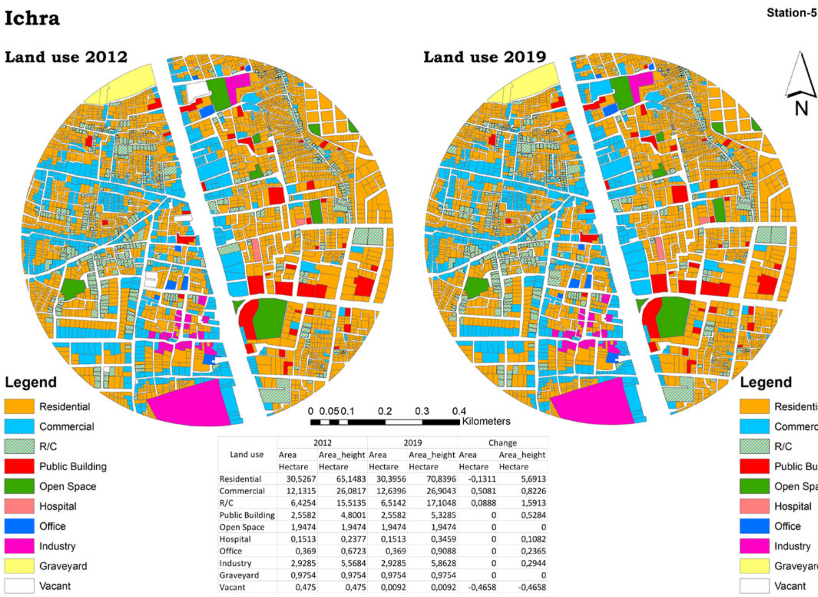


Figure 63 Land-use transformation at Ichra station

can observe in Ichra a trend toward high-rise development for several functions (e.g., residential, commercial, residential/commercial, public buildings, industry, and office), as shown in Figure 63 and Figure 64. Apart from the increase in building heights, redevelopment activities are also evident but mainly for properties abutting the BRT corridor.



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	30,5267	65,1483	30,3956	70,8396	-0,1311	5,6913
Commercial	12,1315	26,0817	12,6396	26,9043	0,5081	0,8226
R/C	6,4254	15,5135	6,5142	17,1048	0,0888	1,5913
Public Building	2,5582	4,8001	2,5582	5,3285	0	0,5284
Open Space	1,9474	1,9474	1,9474	1,9474	0	0
Hospital	0,1513	0,2377	0,1513	0,3459	0	0,1082
Office	0,369	0,6723	0,369	0,9088	0	0,2365
Industry	2,9285	5,5684	2,9285	5,8628	0	0,2944
Graveyard	0,9754	0,9754	0,9754	0,9754	0	0
Vacant	0,475	0,475	0,0092	0,0092	-0,4658	-0,4658

Figure 64 Ichra land-use 2012, 2019

7.2.6 Station-6: Kalma Chowk

Kalma Chowk is close to one of the main commercial centers of the city (e.g., Liberty Market). Moreover, the only cricket stadium in Lahore is located nearby the station area. Story addition is the major land-use transformation evident on Kalma Chowk station, as shown in Figure 65.

A significant transformation is evident in commercial use, for which the covered area is increased by 4.20 hectares but mainly by adding stories (see Figure 66).

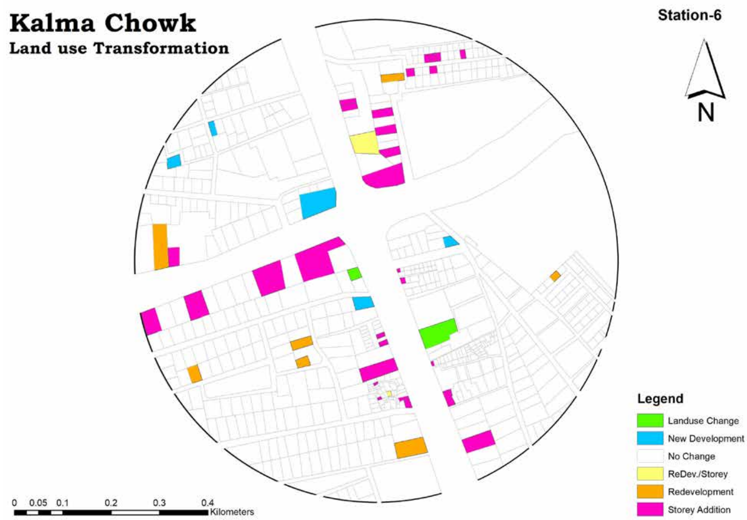
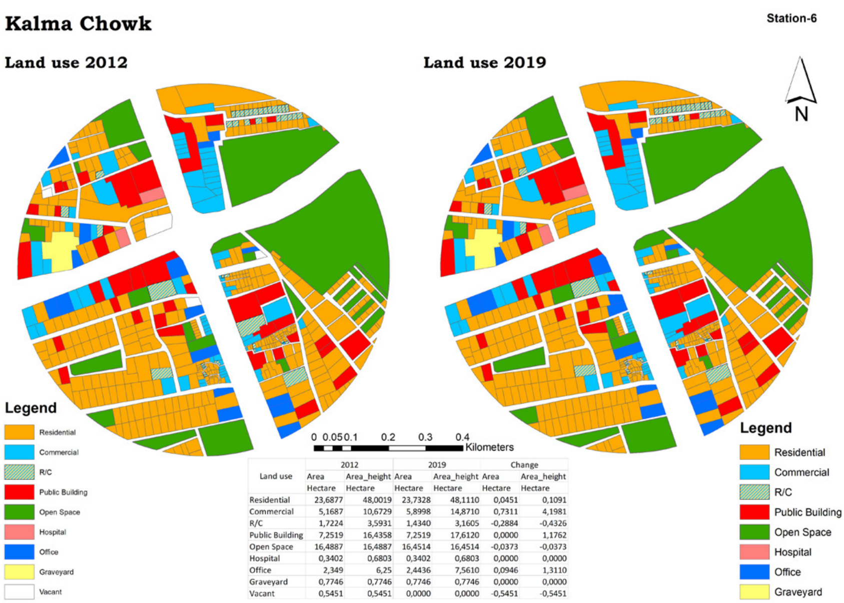


Figure 65 Land-use transformation at Kalma Chowk station



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	23,6877	48,0019	23,7328	48,1110	0,0451	0,1091
Commercial	5,1687	10,6729	5,8998	14,8710	0,7311	4,1981
R/C	1,7224	3,5931	1,4340	3,1605	-0,2884	-0,4326
Public Building	7,2519	16,4358	7,2519	17,6120	0,0000	1,1762
Open Space	16,4887	16,4887	16,4514	16,4514	-0,0373	-0,0373
Hospital	0,3402	0,6803	0,3402	0,6803	0,0000	0,0000
Office	2,349	6,25	2,4436	7,5610	0,0946	1,3110
Graveyard	0,7746	0,7746	0,7746	0,7746	0,0000	0,0000
Vacant	0,5451	0,5451	0,0000	0,0000	-0,5451	-0,5451

Figure 66 Kalma Chowk land-use 2012, 2019

7.2.7 Station-7: Ghazi Chowk

Residential and commercial use represent the dominant land-uses around Ghazi Chowk station. Between 2012-2019, the land area under residential use declined, however, when building heights are taken into account, an overall increase in the coverage area for residential use is evident. The land area, as well as building heights for commercial use, are also increasing. Similarly, for residential/commercial and public buildings, land area and building heights are increasing. A decline can be observed in vacant land due to an increase in development activities around the station. Land-use transformation is evident from Figure 67 and Figure 68, which show a variety of land-use changes.

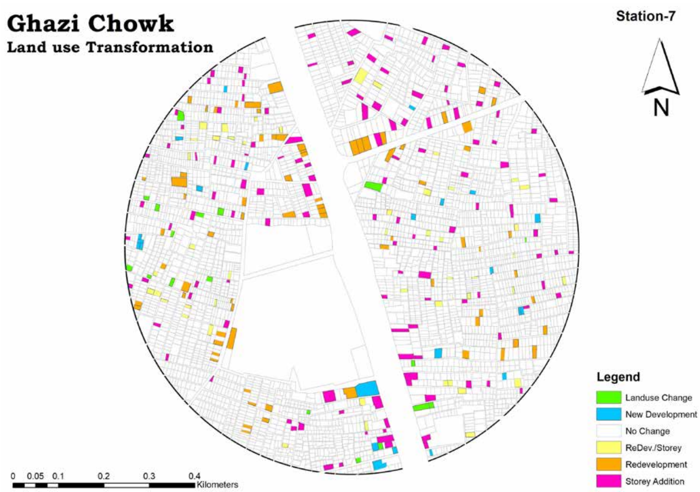
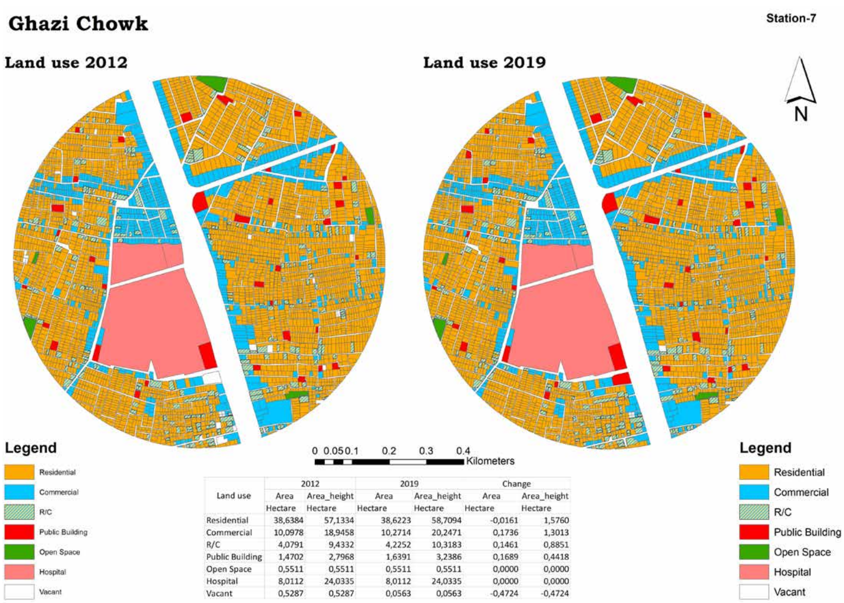


Figure 67 Land-use change at Ghazi Chowk station



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	38,6384	57,1334	38,6223	58,7094	-0,0161	1,5760
Commercial	10,0978	18,9458	10,2714	20,2471	0,1736	1,3013
R/C	4,0791	9,4332	4,2252	10,3183	0,1461	0,8851
Public Building	1,4702	2,7968	1,6391	3,2386	0,1689	0,4418
Open Space	0,5511	0,5511	0,5511	0,5511	0,0000	0,0000
Hospital	8,0112	24,0335	8,0112	24,0335	0,0000	0,0000
Vacant	0,5287	0,5287	0,0563	0,0563	-0,4724	-0,4724

Figure 68 Ghazi Chowk land-use 2012, 2019

7.2.8 Station-8: Chungi Amar Sidhu

Chungi Amar Sidhu is a predominantly residential area. Commercial use is concentrated around the main roads towards the station. Around the station, there is a major expansion in commercial, residential/commercial, and public building use. For commercial and residential/commercial use, an increase in building height is the main transformation type (Figure 69). Moreover, new development activities can be observed, although still, 2.05 hectares are available for new developments (Figure 70).

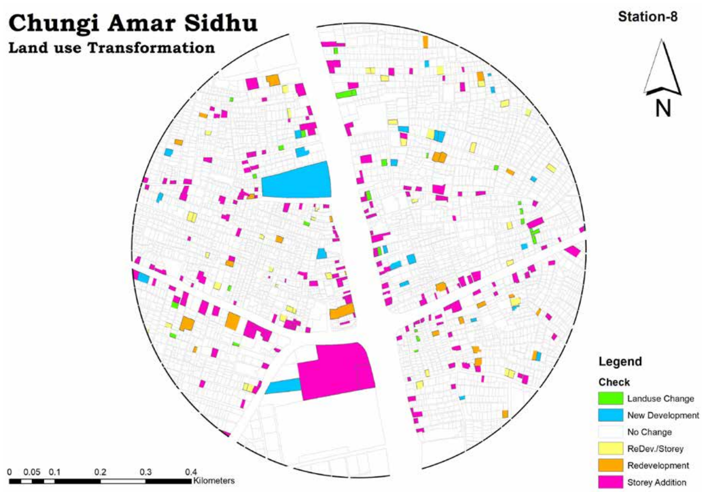
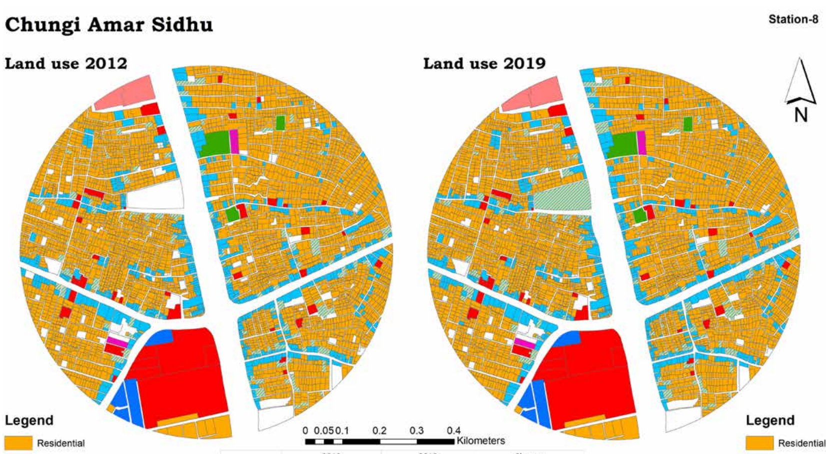


Figure 69 Land-use transformation at Chungi Amar Sidhu station



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	38.84531	88.3182	39.0234	89.6523	0.1781	1.3341
Commercial	7.4681	18.4384	7.5585	22.4457	0.0904	4.0072
R/C	2.2697	5.8880	3.4327	9.9194	1.1630	4.0314
Public Building	6.4231	9.0300	6.4231	11.1580	0.0000	2.1280
Open Space	0.651984	0.6520	0.651984	0.6520	0.0000	0.0000
Industry	0.2246	0.4822	0.2246	0.5036	0.0000	0.0214
Hospital	0.7817	2.3452	0.7817	2.3452	0.0000	0.0000
Office	0.8531	2.3016	0.8531	2.3016	0.0000	0.0000
Vacant	3.4770	3.4770	2.0455	2.0455	-1.4315	-1.4315

Figure 70 Chungi Amar Sidhu land-use 2012, 2019

7.2.9 Station-9: Yohanabad

Yohanabad is similar to Chungi Amar Sidhu catchment area, a predominantly residential area, wherein an increase in density for residential and commercial use is observed. An increase in building heights is also observed along with a decline in available vacant land (Figure 71).

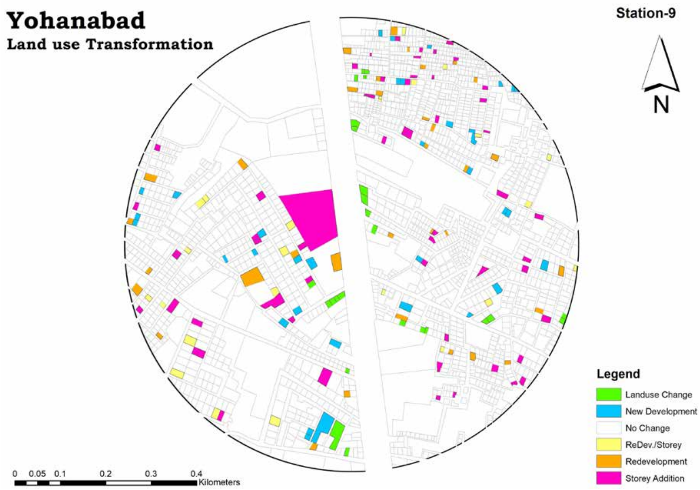
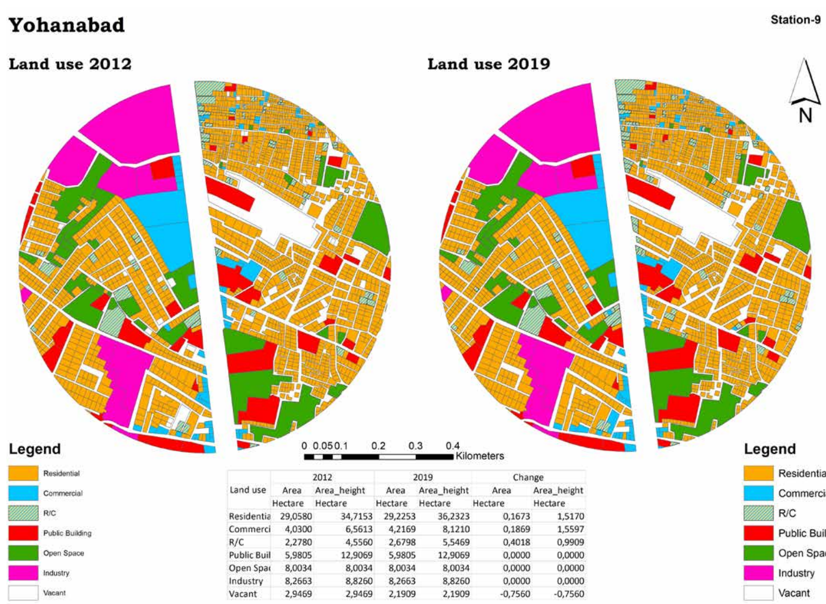


Figure 71 Land-use transformation at Yohanabad station

However, around 2-hectare vacant land is still available for new development, posing potential and opportunity for further transformation in the area (Figure 72). Interviews with local development authorities (Lahore Development Authority) also indicated Yohanabad and Gajjumata as hotspots for land-use transformation in the coming years, mainly in multifunctional ways.



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residentia	29,0580	34,7153	29,2253	36,2323	0,1673	1,5170
Commerci	4,0300	6,5613	4,2169	8,1210	0,1869	1,5597
R/C	2,2780	4,5560	2,6798	5,5469	0,4018	0,9909
Public Buil	5,9805	12,9069	5,9805	12,9069	0,0000	0,0000
Open Spac	8,0034	8,0034	8,0034	8,0034	0,0000	0,0000
Industry	8,2663	8,8260	8,2663	8,8260	0,0000	0,0000
Vacant	2,9469	2,9469	2,1909	2,1909	-0,7560	-0,7560

Figure 72 Yohanabad land-use 2012, 2019

7.2.10 Station-10: Gajjumata

Gajjumata is the south terminal station with predominantly industrial activity in its catchment area. All types of land-use transformations are evident, new developments, story addition, and redevelopment are the most dominant ones (Figure 73). Along with an increase in industrial use, new commercial development is also observed in the area (See Figure 74).

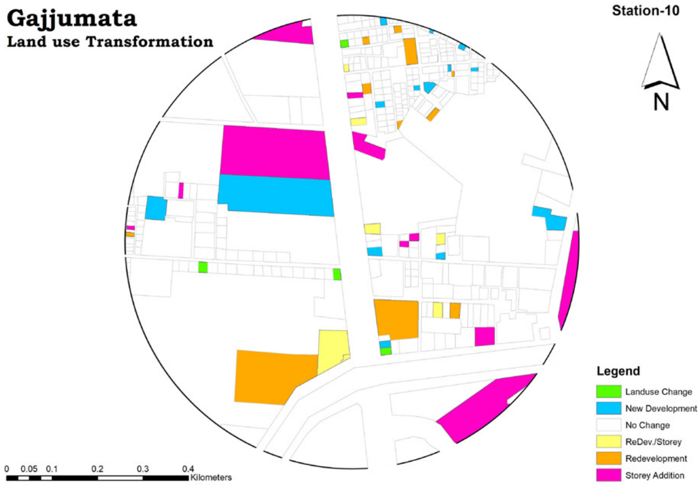
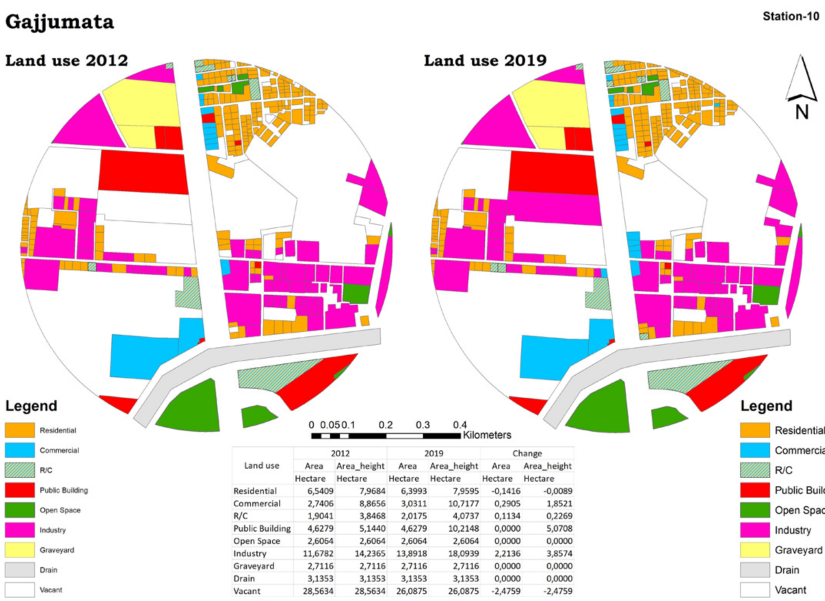


Figure 73 Land-use transformation at Gajjumata station



Land use	2012		2019		Change	
	Area	Area_height	Area	Area_height	Area	Area_height
	Hectare	Hectare	Hectare	Hectare	Hectare	Hectare
Residential	6,5409	7,9684	6,3993	7,9595	-0,1416	-0,0089
Commercial	2,7406	8,8656	3,0311	10,7177	0,2905	1,8521
R/C	1,9041	3,8468	2,0175	4,0737	0,1134	0,2269
Public Building	4,6279	5,1440	4,6279	10,2148	0,0000	5,0708
Open Space	2,6064	2,6064	2,6064	2,6064	0,0000	0,0000
Industry	11,6782	14,2365	13,8918	18,0939	2,2136	3,8574
Graveyard	2,7116	2,7116	2,7116	2,7116	0,0000	0,0000
Drain	3,1353	3,1353	3,1353	3,1353	0,0000	0,0000
Vacant	28,5634	28,5634	26,0875	26,0875	-2,4759	-2,4759

Figure 74 Gajuumata land-use 2012, 2019

7.3 Impact Categories (Typology)

Above, we briefly described the transformations around each of the BRT-stations. We tried to cluster these into exemplary typologies of the BRT corridor. Major distinctive criteria include densification at parcels (addition of story), the new development at vacant spaces, transformations within the functions of properties, redevelopment with addition of stories, and no change. This resulted in the following exemplary typologies.

7.3.1 Functional Change

This typology includes all those areas for which land-use change can be observed without much change in the structure of the properties or new developments. Only around 0.7% of them have undergone some type of land-use transformation. Shahdhara is the station witnessing maximum transformation activities in this respect. Moreover, our study shows that the demand for commercial activities is the most prominent driver, especially in downtown areas like Timber Market, Qartaba Chowk, and Ichra. Therefore, most of the properties in these catchment areas have converted land-use either from residential to commercial or from residential to mixed land-use. These transformations along the BRT corridor provide new possibilities for business development. We observed these transformations to commercial use mostly along the BRT corridor.

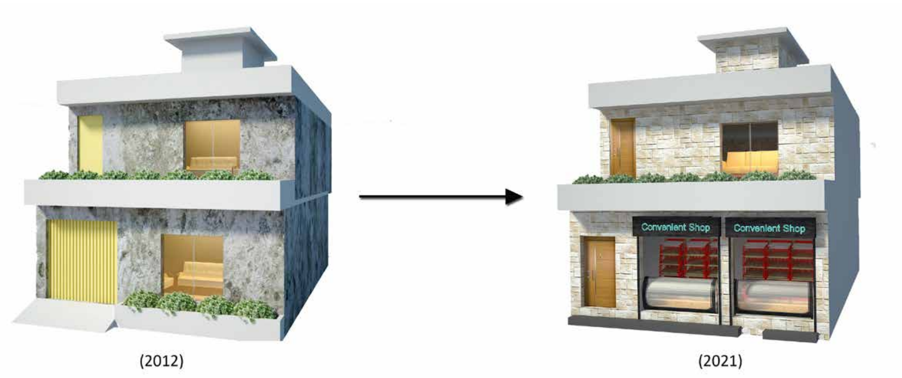


Figure 75 Abstract Images for Functional Change

7.3.2 Structural Change

The catchment areas are predominantly experiencing structural changes of buildings (e.g., redevelopment or story addition) that fall under this typology. The results show that 6.5% of all the properties along the BRT corridor experience these structural changes (1.2% redevelopment, 5.3% addition of story). Story addition is especially witnessed in the catchment area of Ichra Station because this area is a hub of business activities and an ideal place for businessmen and residents. In contrast, stations like Ghazi Chowk, Shama Chowk, and Timber Market are observing predominantly redevelopment activities. These redevelopment activities are due to the dilapidated condition of the former housing and their proximity to BRT stations. The availability of limited space for new development is the reason for the trend to story addition in downtown areas.

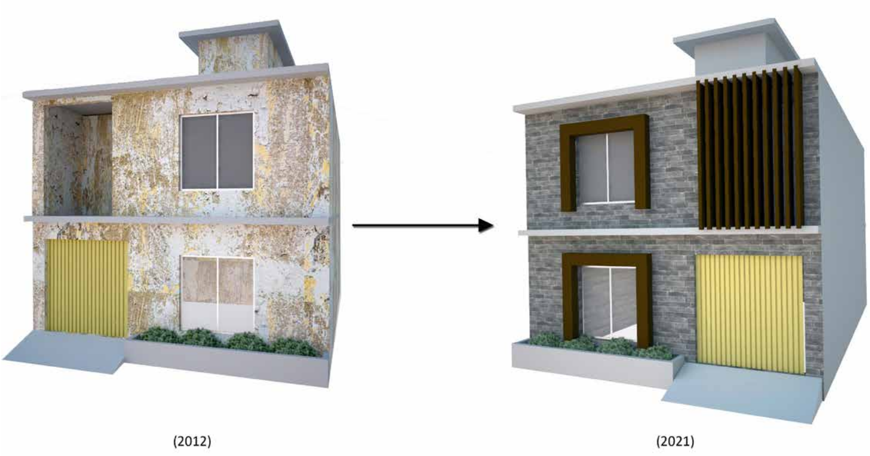


Figure 76 Abstract Images for Structural Change (Redevelopment)

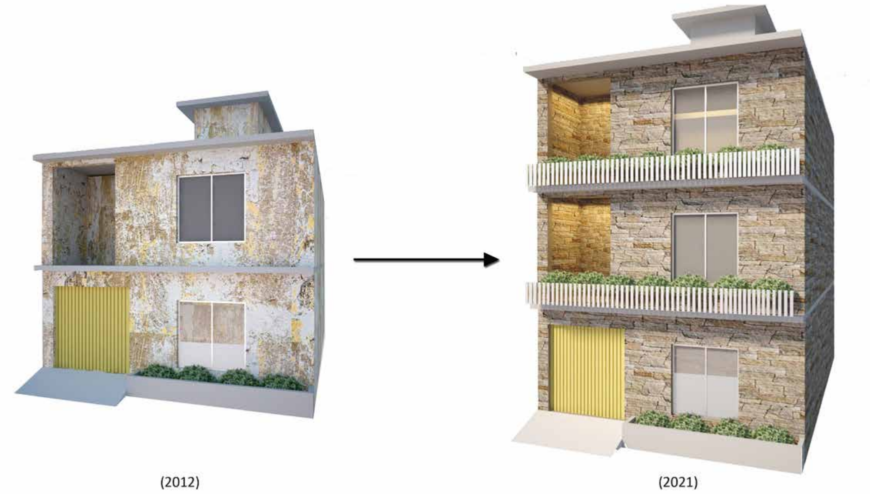
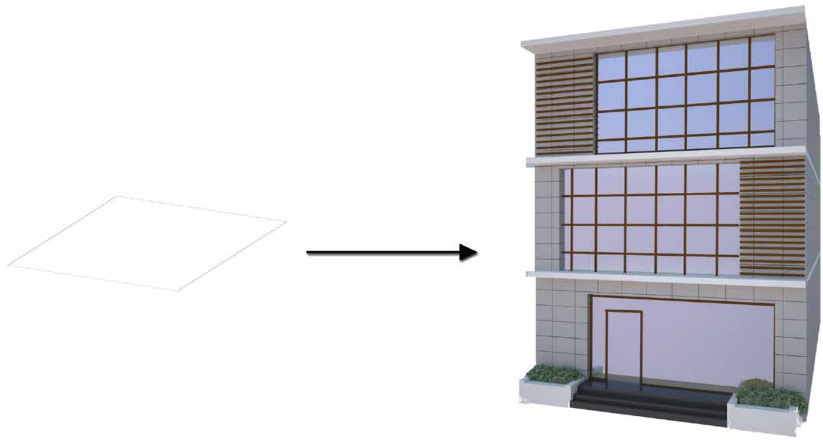


Figure 77 Abstract Images for Structural Change (Storey Addition)

7.3.3 New Development

This typology deals with original vacant properties, which are transformed into urban areas mainly to accommodate the growing demand for housing and new businesses. The analysis reveals that 0.5% of properties within the studied catchment areas are developed after the implementation of BRT. Most of these developments are evident in catchment areas further away from downtown areas, like Yohanabad and Gajjumata, because of land availability. BRT stations in downtown areas are already congested, and the unavailability of vacant land around these stations has encouraged people to build higher.

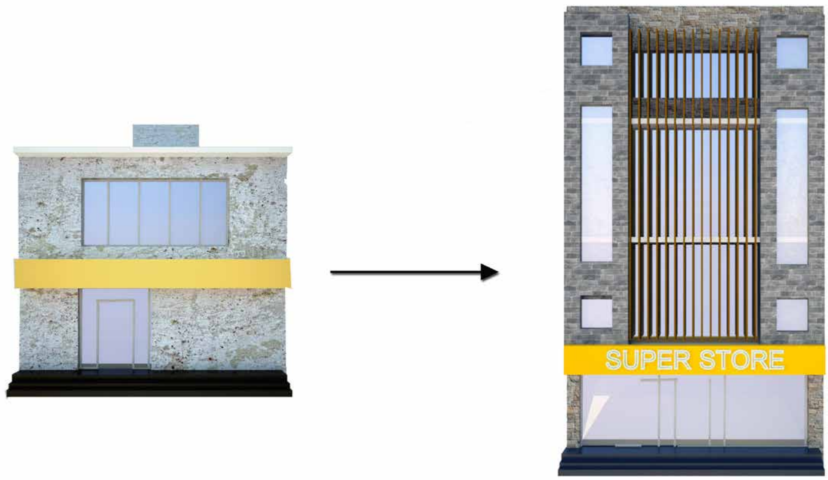


(2012) (2021)

Figure 78 Abstract Images for New Development

7.3.4 Mix Transformation

This typology includes redevelopment activities as a result of the addition of stories to existing properties. The results indicate that some 1.3% of all the properties in the respective catchment areas have gone through a mixed transformation. These kinds of transformations are predominant in catchment areas like Timber station, Gajjumata, and Ghazi Chowk station. Some areas around Ichra station have also gone through such a mixed transformation.



(2012) (2021)

Figure 79 Abstract Images for Mix Transformation

7.3.5 No Change in Urban Development

Within this typology, those areas are included that have not experienced any change after the inauguration of BRT. There are around 91% of properties in the study area, which account for this kind of development. This is partly due to the fact that BRT has only been in service for seven years, and the fact that it was not possible given the existing (planning) conditions in these spots. All the transformations, which account for 9% of the properties in the study area, have happened in the absence of a land-use policy. Moreover, field study reveals that, if given appropriate conditions by changing building by-laws and financial support, people would like to make land-use transformations on these 91% properties and they have not seen any transformation so far.

7.4 Urban Density

Next to the urban development explained before, it is also important to know how the population density has changed after BRT implementation. Besides population density, change in building density is an essential aspect to explore given the land-use transformations in the studied catchment areas. To measure the change in population density, we have used data from the Bureau of Statistics Punjab. However, these are available on the Union Council level, to get more detail, additionally, filled-in survey data have been used to calculate any change in population density on building level. Based on these insights, Figure 79 presents the change in population density from 2011 to 2016 in the studied areas. Population density (pop/acre) for high-density areas changed from 268 to 299 between 2011 and 2016. This increase in population density is more apparent around the BRT corridor compared to the general pattern of Lahore. All the analyzed stations are experiencing an increase in population density. The catchment areas in the northern part of the BRT line, such as the Timber market, Qartaba Chowk, Shama Chowk, and Ichra experienced a greater change in population density compared to BRT stations in the periphery of Lahore (south-direction). Consequently, the aforementioned areas are becoming more congested after the implementation of BRT.

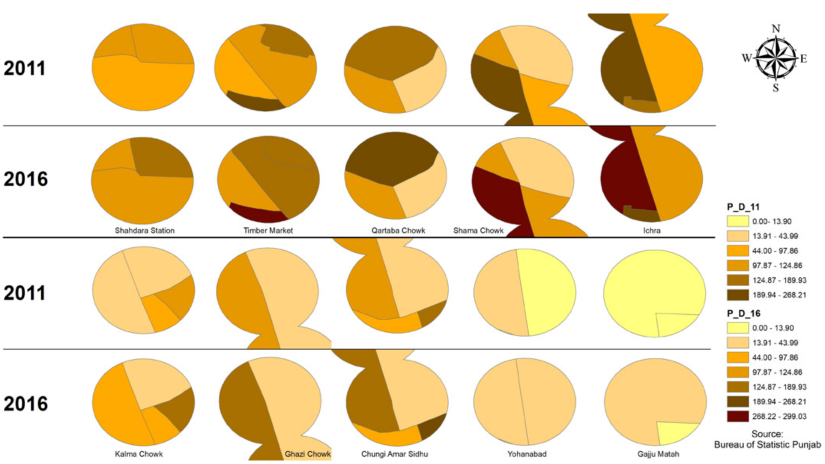


Figure 80 Change in population density (pop/acre)

In addition to that, we explored ways in which urban density has changed for specific land-use on a given location. Analysis of land-use change from 2012 to 2019 shows that urban density for residential use increased the most around the BRT stations, in general. However, at the same time, a few stations (e.g., Timber, Qartaba) also witnessed a decline in urban density for residential use, which is due to land-use transformation (e.g., from residential to other uses). The demand for commercial use on these stations escalated land-use transformation converting them to major commercial nodes. Concerning commercial use, however, urban density generally escalated throughout the study area. This illustrates a trend towards commercialization along the BRT route. Moreover, intensification of residential/commercial use is also evident around the majority of BRT stations except for Timber and Kalma Chowk stations. It is important to mention here that
Table 22 only depicts the variation in urban density, it does not show the actual residential or commercial use in an area. For example, Ichra Station has shown more increase in urban density of residential use than commercial, but this does not mean that residential use is predominant in Ichra Station area. In fact, this station is a predominantly commercial area. An increase in urban density/covered area for residential use is either due to the conversion of other land-use or an increase in building height of residential properties.

Table 22 Change in building density 2012-2019

Land-use	**Area (Hectare)**									
	Shahdhra	**Timber**	**Qartaba**	**Shama**	**Ichra**	**Kalma**	**Ghazi**	**Chungi**	**Yohana-bad**	**Gajjumata**
Residential	0.38	-0.25	-0.67	2.54	5.69	0.11	1.58	1.33	1.52	-0.01
Commercial	10.77	7.95	2.74	1.55	0.82	4.20	1.30	4.01	1.56	1.85
R/C *	1.47	-3.11	0.51	0.33	1.59	-0.43	0.89	4.03	0.99	0.23
Public Building	0.09	0.82	0.00	0.32	0.53	1.18	0.44	2.13	0.00	5.07
Industry	-0.08	0.00	0.00	0.00	0.29	0.00	0.00	0.02	0.00	3.86
Hospital	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00	0.00	0.00
Office	0.00	0.00	0.00	0.09	0.24	1.31	0.00	0.00	0.00	0.00

* Residential/Commercial (both lands uses on same property)

7.5 Determinants of Land use Transformation

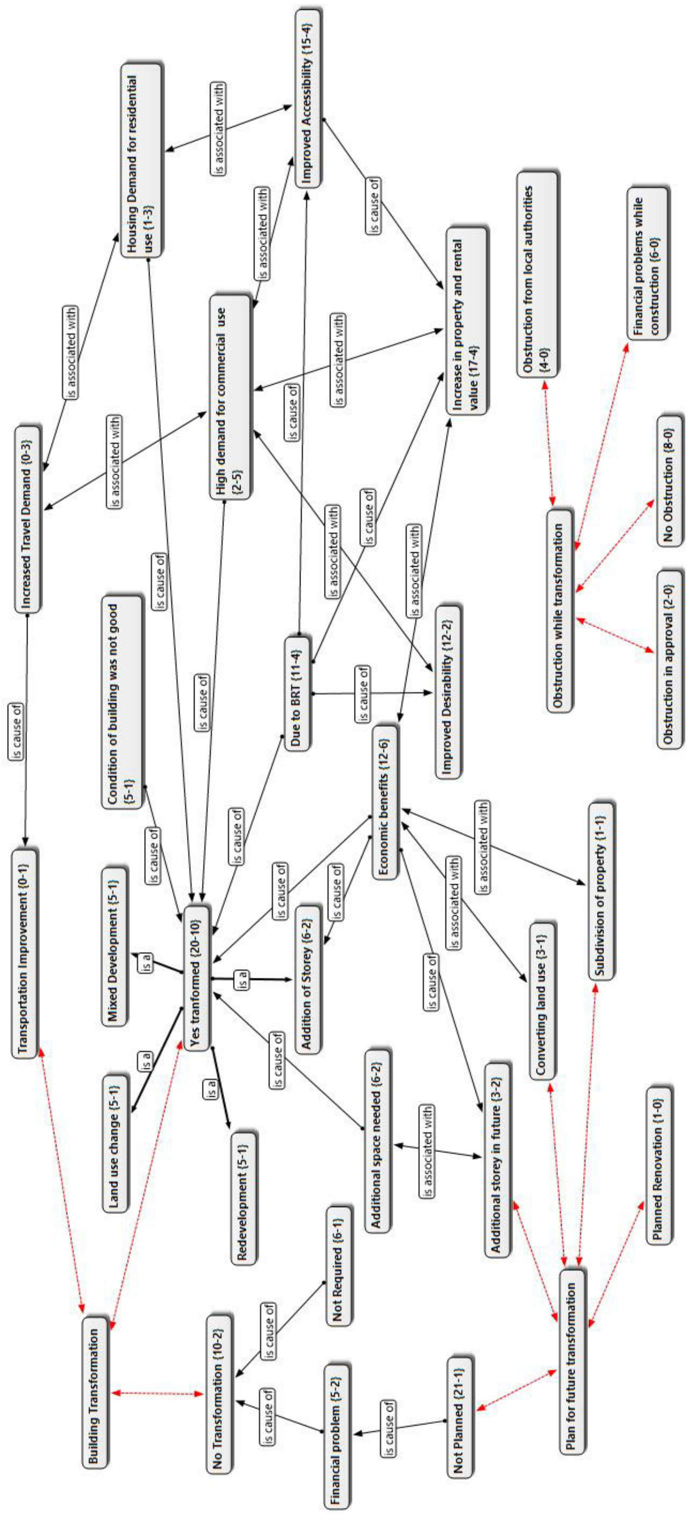
Section 6.1 explained the land-use transformations that have occurred after the development of bus rapid transit (BRT) in Lahore, Pakistan. However, it is not clear from the above discussion whether this transformation is due to BRT or there are other external factors attached to it. Therefore, additional interviews have been conducted with the stakeholders (i.e., property owners) to discern the determinants prompting land use transformation. In total, 30 individuals were interviewed and their responses were

analyzed using Atlas.ti. These interviews with stakeholders mainly explore the land-use transformation, determinants of these transformations, the role of BRT, and future plans of the stakeholders (annex-B). The main themes/node group were introduced as BRT impacts, the reason for transformation and type of transformations, and their interrelation was explored with various nodes and sub-nodes. The results of the analysis are presented through a mental map (see Figure 80). The property owners who have not made any land use transformation were also interviewed to identify the rationale that restricts land use transformation. Mainly two reasons were identified from the interview that restrains people from making any structural change. First either the property owners were satisfied with the existing structure or they do not have sufficient financial support to make any change. Moreover, if they were able to acquire sufficient financial resources, most of them would either go for an additional floor on their existing building or would prefer to convert the land use of the property from residential to mix-use (i.e., lower floor for commercial use and the upper floor for residential purpose). Inquiring about the plan approval process, (i.e., whether they got approval from the relevant development authority or not), most of the people mentioned that they did not get any approval for land use transformation. The major reason was that the process of getting approval from the development authority is complicated and takes too much time.
Majority of the people interviewed have made some type of transformation in their property after the development of BRT. Change in land use, redevelopment, storey addition, and mix development are the types of transformation that have been highlighted by the property owners. From the interviews, two main themes are identified that motivate people to make land use transformation.

Primarily, the development of BRT is one of the main reasons for this transformation. The implementation of BRT has triggered land use transformation in direct as well as indirect ways. During its construction, several properties/buildings on the BRT route were demolished (partially/completely) at specific locations in order to widen the road. As a consequence, redevelopment and improvement in building façade were the significant transformation activities highlighted by the property owners. BRT has improved the accessibility that generates the demand for new commercial activities and housing which has also enhanced the desirability of the area. The new demand engendered results in a land-use conversion from residential to mixed-use and storey addition. Improved accessibility provided by BRT increased the demand for housing and commercial use which ultimately influenced the property values and rental price in the area. More information about an increase in property values can be found under section 8.1.

The second reason for land use transformation was emphasized as the economic benefits (additional income through renting). This determinant also corresponds to the demand generated by BRT. Increased demand for the area has resulted in high rental values and property value. This aspect has encouraged the majority of property owners to construct additional storeys on their present structure. The additional space created is also serving as a source of income for them.

Figure 81 Determinants behind land use transformation



Lastly, other reasons that influenced urban transformation correspond to additional space requirements and deteriorated condition of the building. The residents also had planned to transform their buildings mostly importantly through storey addition and land-use conversion. However, restrictions from local development authority and financial issues are the obstructions being faced while transformation.
In general, according to the stakeholders, increase in property values, better accessibility, and improved desirability are the impacts that their properties have experienced because of BRT. So, we can conclude from the interviews that the development of BRT and anticipated economic benefits are the predominant reasons that prompted land use transformation in Lahore. The demand for new commercial and residential activities along the corridor will generate transport demand in the future. Moreover, the economic benefits also encourage urban development in the study area, and in return, this would generate transport demand. This induced transport demand can be met either by improving the current BRT service or by introducing a new transport service.

7.6 Summary

This chapter explores the urban development impacts of Bus Rapid Transit (BRT) in Lahore. The empirical evidence indicated that BRT has the potential to stimulate land-use transformation. Land-use conversion, redevelopment, storey addition, and mixed development are the types of development being observed around BRT stations. Noticeably, an increase in commercial activities due to land-use conversion has been observed. Next to that, the accessibility benefits provided by BRT and boosted land market has also encouraged people to build higher, resulting in higher vertical density. The extent of transition varies across the entire corridor. Furthermore, population density has also increased from 268 persons/acre to 299 persons/acre. In comparison to general development patterns in Lahore, areas around BRT have become increasingly appealing for residential and commercial activities. Thus, the observed land-use transformations and new activities indicate that BRT in Lahore is somehow successful in encouraging land-use transformation in its vicinity. The interviews with residents also indicated that development of BRT has influenced land use transformation. Moreover, economic benefits (higher rent) have arisen due to improved accessibility which also triggered urban development. Thus, there exists an interrelationship between urban development, transport, and economic development.

8

Economic Development

8.1 Introduction

In previous chapters, we have discussed travel behavior change and urban development transformation. The experience has shown that investment in transit services also influences economic development by promoting inward investment and extension of the labor market. Therefore, this chapter elaborates on the economic developments that transpired in Lahore after the implementation of BRT. First, the property values impacts of BRT have been quantified using Geographically weighted regression followed by the identification of inward investment and extension of the labor market.

8.2 Data Acquisition and Description

8.2.1 Property Data

The property data are based on field surveys performed within a 500-meter buffer of BRT stations in Lahore. Data was cross-verified through District Collector (DC) rate lists and interviews with real estate agents. In total, property values data for 266 units were collected together with physical attributes/characteristics of the property such as property size (PROPSIZE), the number of bedrooms (BEDS), Age of the residential building (AGE), and the total number of storeys (STOREY).

Figure 82 represents a comparison of the percentage change in property values in different areas of Lahore between 2011 and 2019. A prominent change can be observed along the BRT route and this is higher when compared with other areas in Lahore. This indicates that BRT has triggered the property values change along its catchment area.

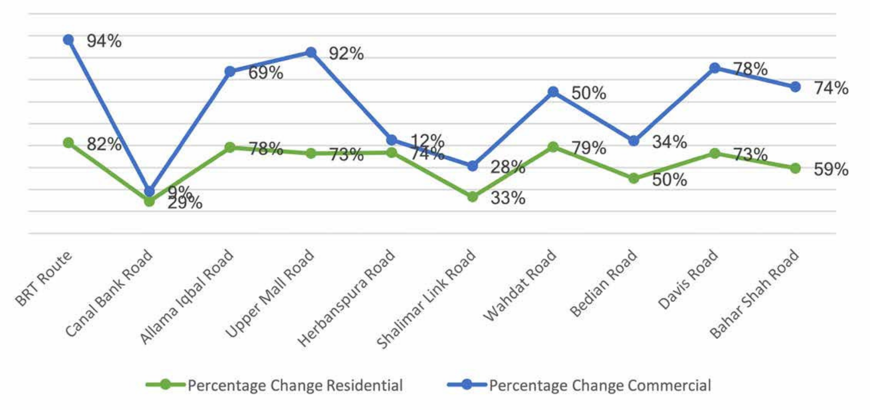


Figure 82 Change in property values in Lahore

Source: District Collector rate Lists

ECONOMIC DEVELOPMENT

A further comparison of price per square foot before and after the development of bus rapid transit along its route is shown in Figure 83 represents a comparison of price per square foot before and after the development of bus rapid transit in Lahore. It reveals that the price (US dollar) has increased after the development of BRT in Lahore similar to other BRT systems around the world. However, it is not apparent whether this increase is due to the implementation of BRT or due to some other indigenous factors. Therefore, this research examines the spatial distribution of uplift in land value and factors influencing land value uplift through the application of geographically weighted regression.

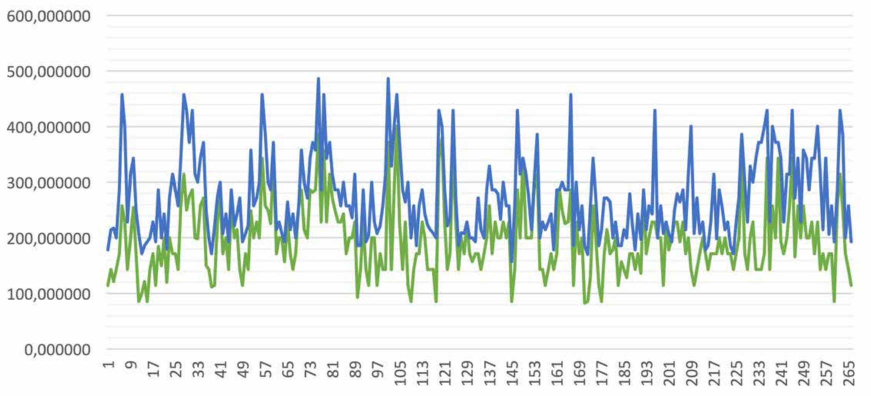


Figure 83 Pre and post comparison of Price per square feet

8.2.2 Data regarding locational attributes

Base map data including BRT route alignment, feeder route, and BRT stations was gathered from Lahore Transport Company (LTC) and Punjab Masstransit Authority (PMA) to show the location of the BRT corridor and transit routes. Geographical information system (GIS) was used to measure the distance between given residential observations and local amenities. Geographical coordinates (e.g. latitude and longitude) were used to accurately locate each observation in a GIS environment. A spatial analysis tool in GIS was utilized to measure the proximity from a residential property to the nearest local amenities. The straight line distance in meters was measured using the Near tool of ArcGIS. The near distance measurement requires two data layers: The location of residential properties (origin) and the location of local amenities (destination). ArcGIS version 10.6.1. was used for this research. Data regarding neighborhood attributes (i.e., Road width) was measured through google map.

In this research, accessibility attributes include the distance to the nearest bus rapid transit station (DBRT), distance to the nearest recreational park (DPARK), and distance to the nearest educational facility (DEDUCATION). In literature, these accessibility attributes have been delineated as the factors that may influence the value of a property. Therefore, It is imperative to include the distance between surveyed properties and public amenities in the analysis. Table 23 describes data used to assess the property value impacts of BRT. In a regression-based analysis, usually, multi-collinearity is observed between some of the independent variables. The coefficient of Pearson's correlation and Variance Inflation Factors (VIFs) are used to detect the correlations between independent variables. A VIFs value of more than 10 and Pearson's correlation coefficient greater than 0.8 shows harmful collinearity (M. Dziauddin, 2019; Orford, 2017). Whereas, researchers and ArcGIS guidelines for GWR guidelines also indicate a VIFs value of less than 7.5 to avoid the problem of multi-collinearity (Nadi & Murad, 2019). In this research, independent variables that produce a variance inflation factor of 7.5 or more and a correlation coefficient higher than 7.5, were detached from the final model. For further accuracy, local multi-collinearity was tested using scatterplots following this independent variable; the number of stories was eliminated from the final model. Subsequently, the hedonic pricing model (HPM) was applied to explore the parameter estimates for independent variables. The performance HPM was tested through Global Moran's I Spatial Autocorrelation test. Finally, the geographically weighted regression (GWR) model was performed to evaluate the changes in local parameter estimates for each location, and results were mapped using inverse distance weighted (IDW) interpolation in ArcGIS. HPM and GWR models were performed using the Semi-parametric GWR-4 version (S-GWR 4.09) developed by Nakaya et al. (2016).

Table 23 Data Collection

Data	Units	Sources
Price/Sq.ft (Dependent variable)	US $	Field Surveys, real estate agents, and DC* rates
Explanatory variables		
Property attributes		
PROPSIZE	Square feet	Field Surveys
AGE	Years	Field Surveys
BEDS	Numbers	Field Surveys
STOREY	Numbers	Field Surveys
Neighborhood attributes		
Road width	Feet	Calculated using Google map
Accessibility		
DBRT	Meters	Calculated using GIS
DPARK	Meters	Calculated using GIS
DEDUCATION	Meters	Calculated using GIS

* District Collector

8.2.3 Descriptive Statistics

Table 24 presents the descriptive statistics for property value and area. Property value has a mean value of 25.50 dollars per square foot with a standard deviation of 6.85. PROPSIZE has a mean of 1502.66 (square feet) with a standard deviation of 857.04.

Table 24 Descriptive statistics

Variables	Units	Mean	S.D.
Price/sq.ft	US $	25.50	6.85
PROPSIZE	Square feet	1502.66	857.04

Figure 84 represents the distance of surveyed properties to the nearest BRT station. The distance ranges from 40 to 553 meters. Most of the properties (69%) fall within 181-439 meters of the BRT station. Figure 85 shows the distance to the nearest park. The least distance is observed on Kalma Chowk and Chunig Amar Sidhu stations. Most of the properties (73%) have a park within 705.15 meters of their surroundings. Distance between surveyed properties and the nearest education facility is represented in Figure 86. However, the majority of the properties (48%) fall within 435-834 meters of an education facility. The least distance to education facility is prevalent on Kalma chowk, Ichra, Yohanabad, and Gajjumata stations.

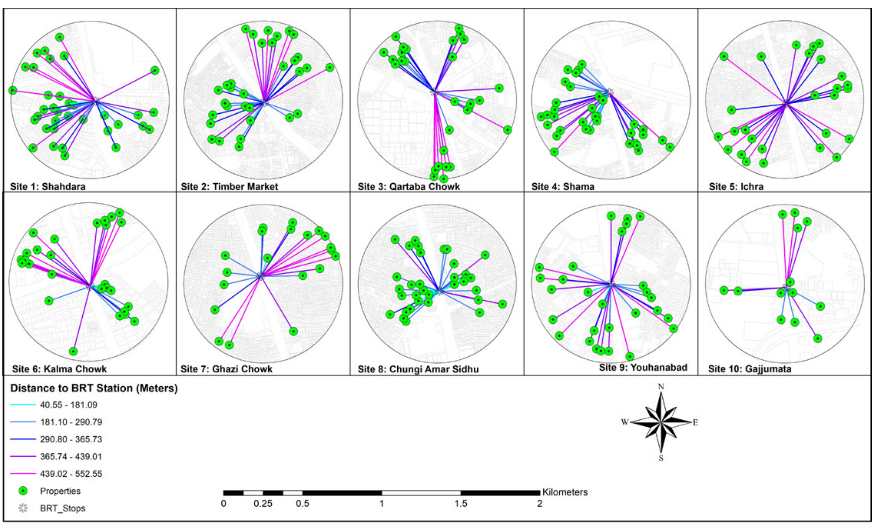


Figure 84 Distance to nearest BRT Station

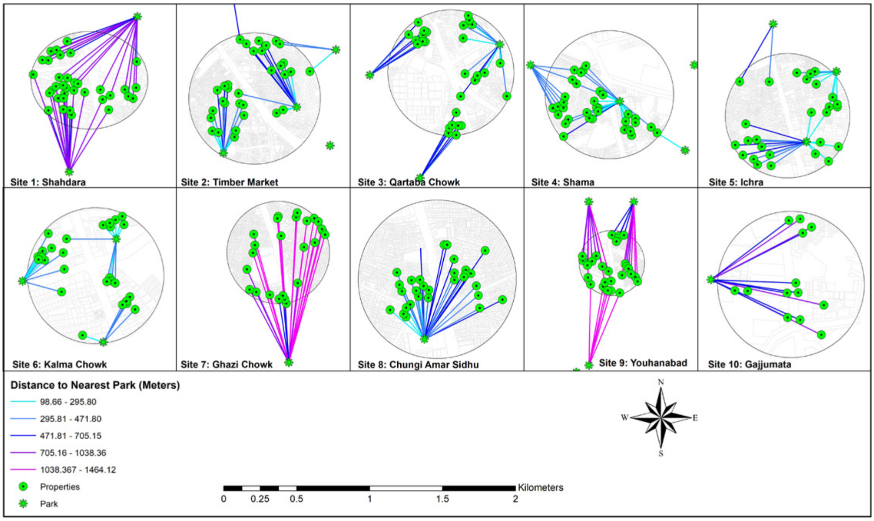


Figure 85 Distance to nearest Park

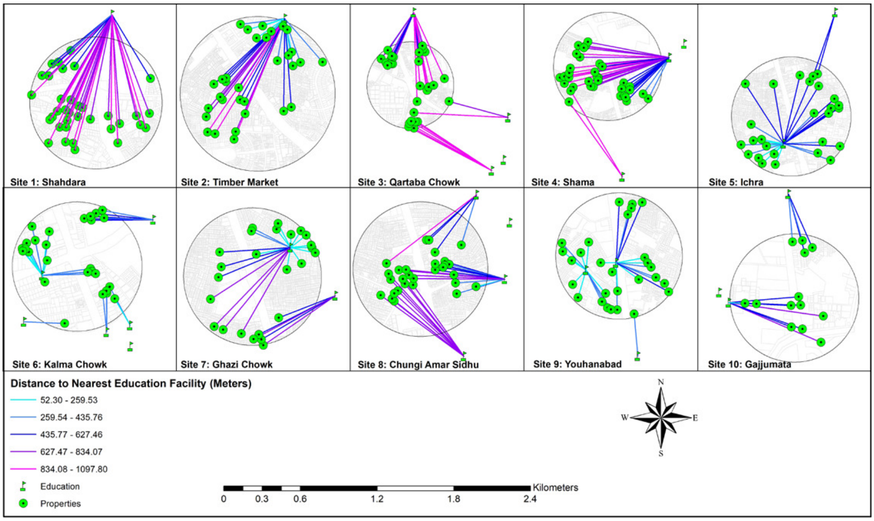


Figure 86 Distance to nearest Education facility

8.2.4 Modeling Approach

In literature, different methodologies have been used to capture the property value impact of transport investment including Regression analysis (D. A. Rodriguez & Mojica, 2008), Propensity score matching (Jorge Andrés Perdomo Calvo, Mendoza, Mendieta, & Baquero, 2007), and Hedonic pricing (Munoz-Raskin, 2010; Jorge Andrés Perdomo Calvo et al., 2007; RODRÍGUEZ & Targa, 2004; Yiming Wang, Potoglou, Orford, & Gong, 2015; Yang et al., 2020). The hedonic pricing model is the most sophisticated and evaluates the land value impact of transport investment by controlling for many factors in a multiple regression model. Hedonic pricing has been considered as the powerful method to appraise real estate (Cervero & Duncan, 2001; M. Dziauddin, 2019; Mulley, 2014). However, global statistical methods often assume a homogeny (stationary) relationship between the dependent and predictor variables over space, which could lead to misleading results whenever applied to a spatial dataset (Nkeki & Osirike, 2013; So, Tse, & Ganesan, 1997). In 2002, to reinforce this weakness, a more refined alternative – e.g. geographically weighted regression (GER) – was developed by Fotheringham, Brunsdon, and Charlton (2003). This accounts for spatial dependency allowing exploration, examination, and modeling of spatial relationship. Therefore, GWR can be utilized to access variation in property value over space during the analysis (Mulley, 2014). Therefore this research combines a hedonic pricing model with geographically weighted regression to capture the property value impact of Bus Rapid Transit (BRT) in Lahore. GWR has widely been used in a variety of fields including urban public transport (Andersson, 2017), poverty (Benson, Chamberlin, & Rhinehart, 2005), real estate (M. Dziauddin, 2019; Liang, Liu, Qiu, Jing, & Fang, 2018; Mulley, 2014) and regional industrialization (Partridge, Rickman, Ali, & Olfert, 2008).
GWR model is a kind of regression model with uses coordinates of the variable to capture local variations in the values of the parameter. A conventional GWR model where property value is the dependent variable Y, presented in equation 1.

$$Y_i = \beta_0 + \sum_k \beta_k X_{ik} + \varepsilon_i \quad (5)$$

Where Y_i is the dependent variable (e.g. property value), X_{ik}, and ε_i are kth independent variable, and the Gaussian error at particular location respectively.

$$Y_i(u_i v_i) = \beta_0(u_i v_i) + \sum_k \beta_k (u_i, v_i) X_{ik} + \varepsilon_i \quad (6)$$

whereas $(u_i v_i)$ is the coordinate of the ith location and coefficients $\beta_0(u_i v_i)$ are characteristics of property at a given location. Another important aspect of GWR is that it allows for the mixing of globally fixed and geographically varying coefficients. For example, in the present research population density and income group are the parameters that are constant over a specific geographic extent.

$$Y_i = \beta_0(u_i v_i) + \sum_k \beta_k (u_i, v_i) X_{ik} + \sum_l \gamma_l Z_{li} + \varepsilon_i \quad (7)$$

8.2.5 Empirical Results

8.2.5.1 Hedonic pricing model

Table 25 represents the results of the hedonic pricing model (HPM) and estimations for geographically weighted regression (GWR). A single parameter estimate set can be obtained from HPM and this single parameter value is used for the entire geographical area. Whereas the GWR model provides local parameter appraisals for every observation including a minimum, maximum, and mean value. The adjusted R^2 for the global model (ordinary least square) suggests that 89 % of the variance in the dependent variable is described by the model. Among the physical characteristics of the property, AGE and BEDS are significantly associated with higher property values. So, ceteris paribus, as the building age increased by one year the house price decline by $1.03/square feet which at the mean equates to approximately $1500. An additional bedroom, keeping other things constant will result in $0.91/square feet increase in house price. At mean, this equals a premium of around $1350. This finding clearly shows that the scarcity of space leads to amplified prices in the housing market. Ceteris paribus, a one-meter increase in the width of road add $0.09 per square feet which, at the mean, equivalent to a premium of almost $130. However, amongst the researched accessibility attributes, proximity to the BRT station is the only statistically significant attribute. The hedonic model specified that ceteris paribus, every one-meter decline in the distance to BRT station is associated with an $0.0136 increase per square feet. This equals $20.44 at the mean.

8.2.5.2 Global Moran's I Spatial Autocorrelation

It is imperative to check the performance of the global model before proceeding further. The performance of the global model is tested through residual (Nadi & Murad, 2019; Nkeki & Osirike, 2013). Non-clustered residuals indicate that the global model i.e. ordinary least square (OLS) has good performance. In this research, the spatial autocorrelation statistic (global Moran's I) test was performed to check the performance of the OLS model. A non-clustered (random) pattern was observed for standard residual (see Figure 87) with a z-score = 0.891572 and Moran index = 0.026047 establishing that the OLS model performed well, so we can proceed further to apply geographically weighted regression (GWR).

Table 25 Results of hedonic pricing model and GWR (n=266)

	Ordinary least square				Geographically weighted regression		
	Coefficient (β)	t-ratio	Sig.	VIF	Coefficient (β)		
					Min.	Max.	Mean
Intercept	41.002528	29.1816	0.000000*	---	37.5643	42.555120	40.8672
PROPSIZE	0.000076	0.461576	0.644786	1.029930	-0.00013	0.000339	0.00007
AGE	-1.035320	-19.50338	0.000000*	5.125604	-1.06135	-0.94841	-1.0243
BEDS	0.913908	5.794272	0.000000*	3.619213	0.9151	0.9123	0.8619
Road Width	0.091814	5.365859	0.000000*	1.575329	0.05347	0.108891	0.0797
DBRT	-0.013604	-5.298201	0.000000*	2.773447	-0.01475	-0.011719	-0.0133
DPARK	0.000260	0.604430	0.546092	1.061000	0.000113	0.000397	0.0003
DEDUCATION	0.000762	1.391476	0.165290	1.059038	0.000351	0.000855	0.0006

Notes: Goodness of fit: Adjusted R^2=0.89 (hedonic pricing model); Adjusted R^2=0.90 (GWR). AIC = 1200 (hedonic pricing model); AIC = 1194 (GWR). *significant at 0.001

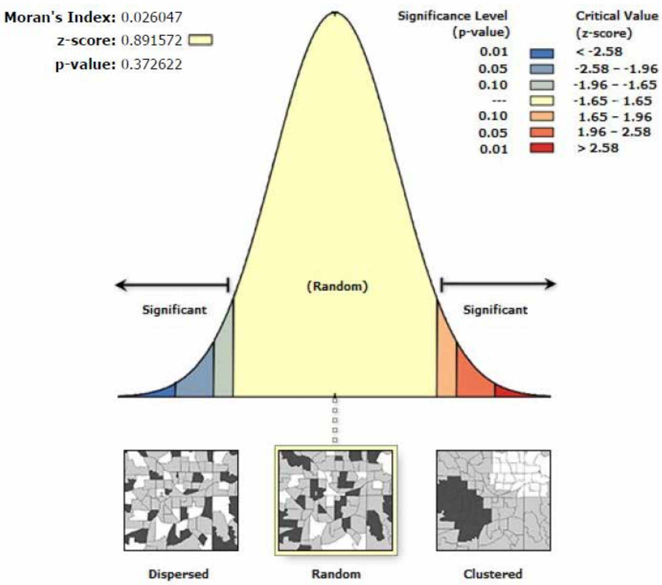


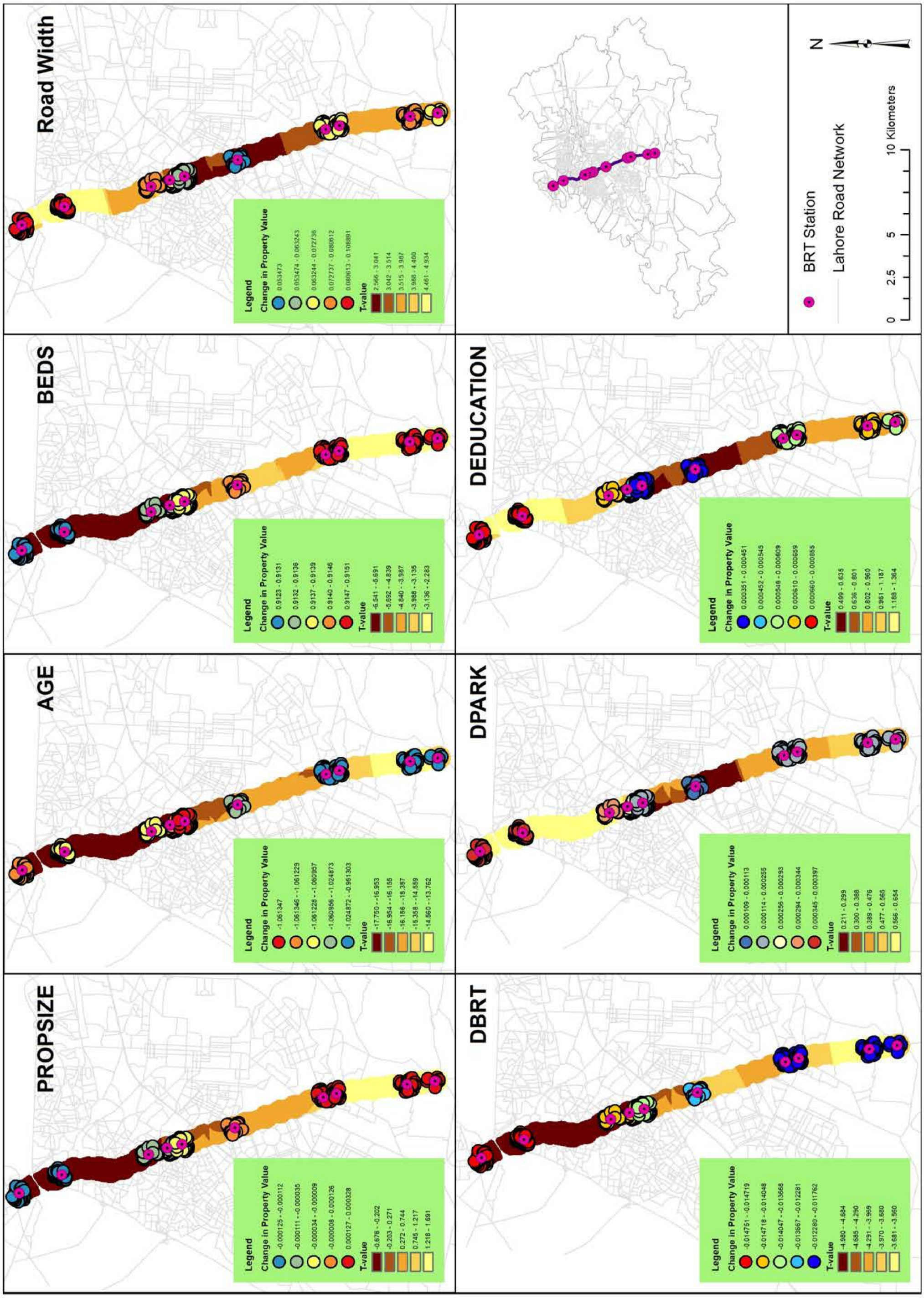
Figure 87 Global Moran's I spatial autocorrelation (Non-clustered residual)

8.2.5.3 *Geographically Weighted Regression*

The positive impacts of BRT station on residential property values have been explained in the preceding section. However, in the global model, these positive impacts have been constantly applied over the entire geographical area. On the other hand, GWR can yield a local parameter estimate for every relationship and every single location. The GWR as a local model offers better results than the global model which is depicted through a lower AIC (1194 over 1200) and better adjusted R2 value (0.90 over 0.89). As earlier described a GWR model produces local parameter estimates for each variable and every location. Subsequently, following suggestions from M. Dziauddin (2019) and Mennis (2006), we have mapped t-value and local parameter estimates (see Figure 88) using inverse-distance weighted (IDW) interpolation in GIS. An important aspect of GWR is the mapping of the spatial distribution of the independent variables. It is possible that some independent variables (DPARK and DEDUCATION in this research) might be non-significant in the hedonic model (global model) but changes significantly over the geographical area, which can be revealed through local parameter estimates measured through GWR modeling. All output local parameter estimates produced by the GWR model are mapped (see Figure 88). Since the primary goal of this research is to identify the impacts of BRT on property values, only the spatial distribution of local estimates for accessibility variables is discussed here in detail.

DBRT represents the proximity to the BRT station. It has a clustering of high negative value (shown by red color) in the north direction, which indicates a high premium of between $0.01475 per sq. ft. to $0.01471 per sq. ft. A negative estimate value indicates a positive premium. At the mean, this equals a premium of $22.25 to 22.09. Moreover, the relationship between increased property value and accessibility to BRT station is more significant around Shahdhara, Timber Market, Qartaba Chowk station. These stations are also dominated by commercial activities, which might be the reason for a strongly positive relation. On the other hand, BRT stations including Gajjumata, Yohanabad, and Chunig Amarsidhu in the south direction, experience less premium (shown by blue color), still a significant association between property value and proximity to BRT stations. The properties towards the south terminal of BRT gain a premium of between $0.01228 per sq. ft. to $0.01176 per sq. ft. This equals a mean premium of $18.44 to 17.66. Overall for the entire corridor, a decline in the distance to the BRT station is associated with an increase in property value. A non-significant association is evident between property value and the distance to a park (DPARK). Similarly, a non-significant relationship is observed between property value and distance to educational facilities over the entire BRT corridor. Despite these non-significant relations, a higher premium due to proximity to the park is evident at stations including Shahdhara, Timber Market, Qartaba Chowk located in the north. Similarly, a higher premium because of proximity to the educational facility is evident for the BRT stations located in the north (see Figure 88).

Figure 88 Map for the local parameter estimates of the accessibility parameters for the BRT, Lahore



8.3 Inward Investment and Expansion of Labor Market

Through the discussion in section 6.1, it becomes clear that commercialization has increased in all the studied catchment areas throughout the corridor. However, to gain more insight, we further investigated by inquiries how much money has been invested by the investors in the areas and if this has also influenced the labor rate in the studied area. Through this, the external benefits of BRT can be measured more precisely. In this respect, our field surveys and interviews from commercial properties along the BRT corridor in Lahore, show that areas served by BRT are able to perceive an inward investment of approximately 22,000 million rupees (US $140 million). Most of these investments correspond to the upgrading of existing commercial properties (addition of storeys or redevelopment) or the development of new commercial plazas as shown in Figure 89.

Figure 89 New development along the BRT corridor

The station-wise breakdown of inward investments is given in Figure 90. This shows that inward investment is not limited to specific areas/stations and that every station was able to attract inward investment. However, Kalma Chowk and Chungi Amar Sidhu catchment areas have managed to attract higher inward investment due to the development of some multi-story commercial centers on available vacant land. The BRT stations located toward the north near "Walled City" have not experienced many new investments since these catchment areas are limited to the upgrade of existing commercial businesses. The unavailability of vacant land is one of the constraints for new development activities. Secondly, as outlined by building by-laws for commercial properties, a setback of 30 feet, irrespective of the property size, is required, which is indeed difficult to attain on small-size plots. Hence, it further hinders businesses to invest in such properties in already dense areas. Therefore, few multi-story developments are observed on stations with small plot/property sizes. Stations like Kalma Chowk (see Figure 64) have large parcels in the form of more developable land, ultimately attracting more investors. This inward investment also helps to generate additional jobs in the vicinity of BRT. The field surveys from commercial properties indicate that approximately 800 additional jobs are added to these stations after the development of BRT.

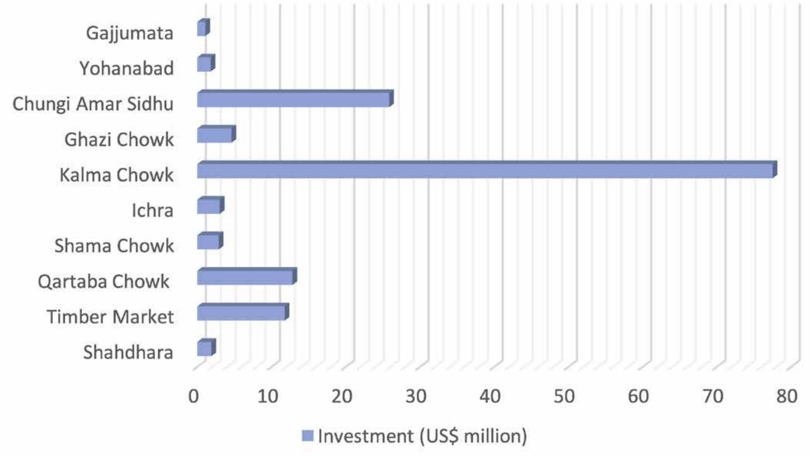


Figure 90 Inward investments

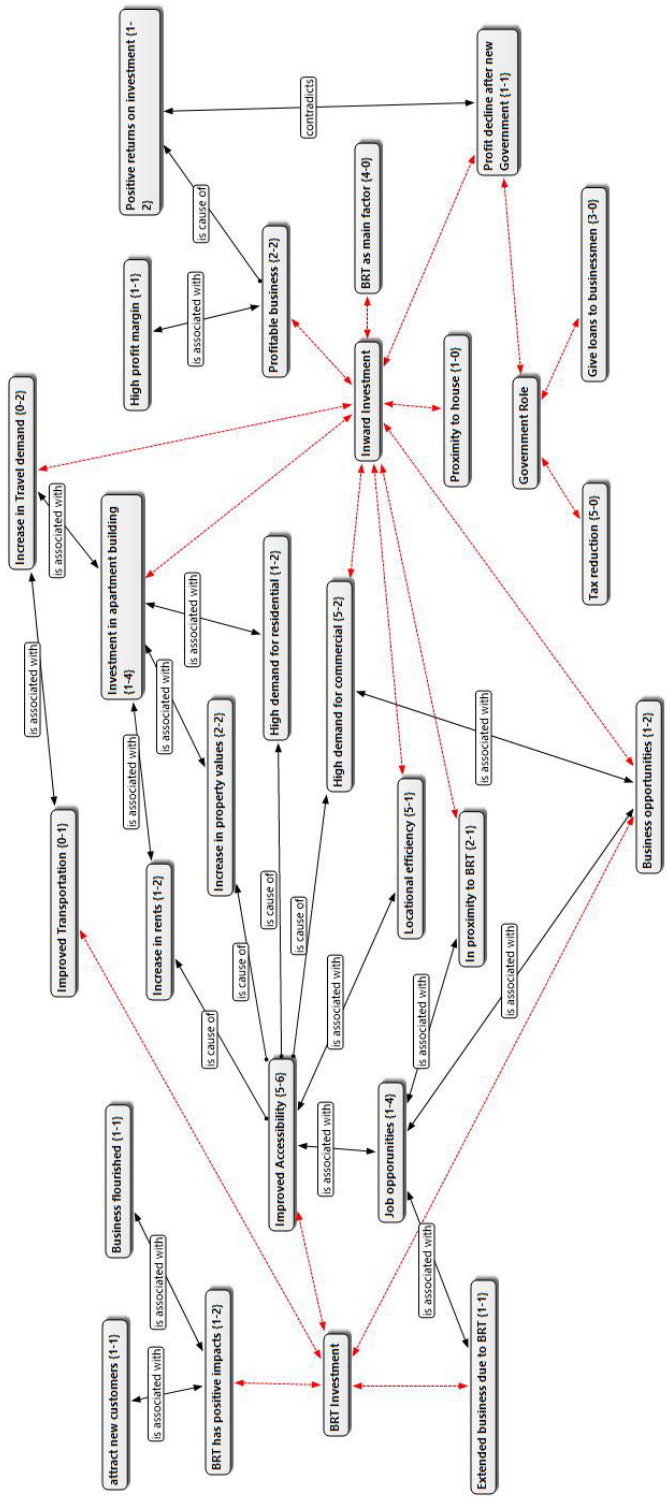
This is expected to be further increased in the near future as a few commercial projects are still under construction (see Figure 91).

Figure 91 Under construction projects

8.4 Determinants of Inward Investment

Section 8.3 illustrates the inward investment followed by the development of Bus Rapid Transit (BRT). It can be observed that considerable economic investments have been made after the development of BRT. Hence, it was imperative to include the investor's point of view to explore the determinants of inward investment and the role played by BRT to attract these investments. For this purpose, seven investors were interviewed and their responses were analyzed using software Atlas.ti. The face-to-face interviews were conducted with the investors along the BRT corridor. For an even distribution of sample both large and small scale investors were interviewed. The purpose of these interviews was to investigate the reasons for investment, the effect of BRT on business opportunities, parameters for locational choice, and return on investments (annex-c). The results of the interviews are presented as a mind map in Figure 92.

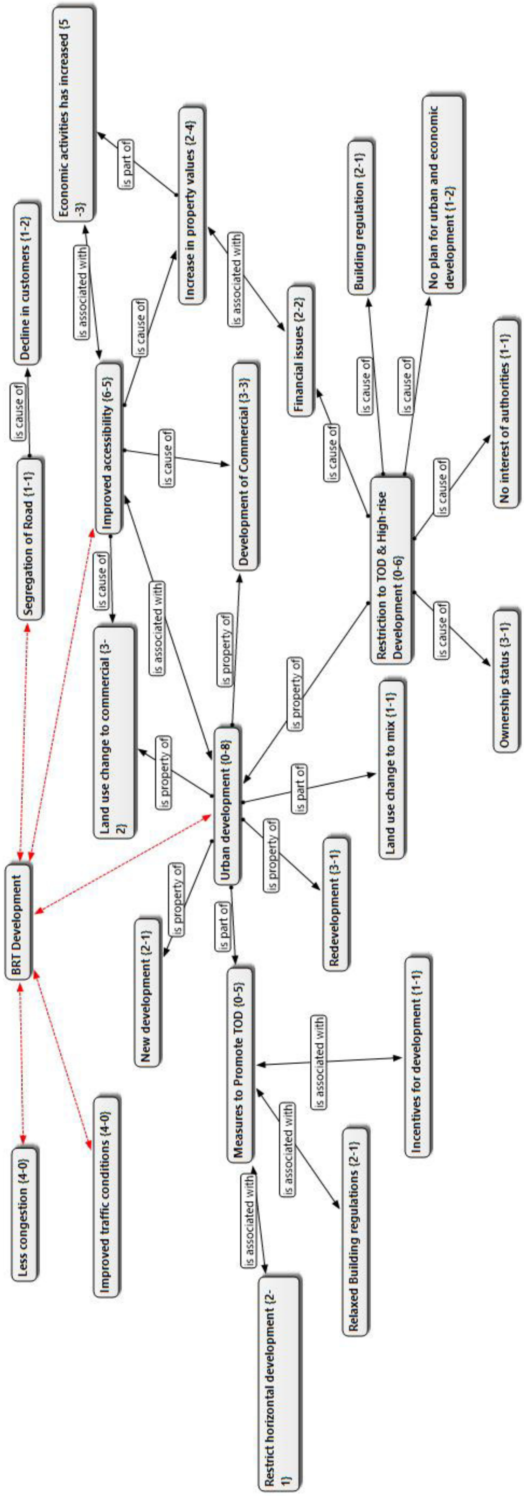
Figure 92 Determinants of Inward Investment



According to the investors, BRT is one of the main reasons for investing around the corridor. Therefore, areas around BRT stations were seen as a great potential opportunity for investing. The small business owners indicated that people using BRT preferred shopping nearby BRT stops/stations. Moreover, few large investors also consider investing along BRT keeping in view the business development trend which is nearby or growing within.
In addition to this, the investors also consider BRT as the main factor for investment as it connects people from various parts of the city (peripheral areas with the downtown area). The locational efficiency resulting from improved accessibility also encourages inward investments. The demand for new commercial and residential activities along the corridor is indeed an urban development phenomenon, which is associated with improved accessibility also triggers inward investment. Improved accessibility benefits delineate by BRT investment have influenced the property and rent values. Due to which investments have been observed in the construction of apartment buildings. The accessibility benefits provided by BRT have linked the various areas in the city and have created job opportunities. The interviewee also indicated that there are more business opportunities in proximity to BRT. For investors investing along BRT was a good decision compared to other locations in the city as this area has a lot of potential for new business development. Moreover, after the construction of BRT, their businesses have flourished as it brings new customers from far-reaching areas by providing them with better accessibility. The investors also indicated that besides BRT there are other reasons as well to invest in this particular location that include high demand, high business profitability, and locational efficiency.
When inquired about the returns on their investment, it was identified that it varied across all business types. For the majority of businesses, returns are positive. However, the prevailing economic condition of the country and new reforms in the taxation system has affected the profit ratio.

According to investors government can ease the taxation system and provide tax holidays for new businesses. Besides, they indicated that loans on low-interest rates can help new businessmen to establish their businesses along BRT.
Conclusively, the interviews with investors indicated three ways in which BRT helped for bringing new investment along the corridor. First, the development of BRT has generated the demand for land uses including commercial and housing that has encouraged investors to invest along the BRT corridor. Secondly, BRT has improved the accessibility that leads toward locational efficiency for example the locations which were not considered for commercial or residential activities have gained potential and are now being used for these purposes. Moreover, it has also brought new customers; promoting commercial activities and investment in the study area. Last but not the least, an increase in property and rent values has been witnessed after the development of BRT as a result of investment which triggers the development of apartment buildings along the corridor. In return, this new development of apartments and commercial plazas will increase the travel demand in the future. Then there would be a need for an improved BRT service or new transportation mode with high travel capacity.

Figure 93 Mind Map for Real Estate Agents



8.5 Interview with Real Estate Agents

The foremost purpose of interviewing real estate agents was to cross-verify the property value data gathered through field surveys. Moreover, it also provides the general viewpoint of people about development trends, improvements in the area in terms of urban development, economy, and travel behavior, and most importantly the constraints for transit-oriented development (annex-A). A sample of twelve was selected to collect information from real estate agents. Figure 93 shows the mind map presenting the views of real estate agents. The interviews with real estate agents reveal that almost all areas around the BRT corridor have experienced an increase in property values due to improved accessibility. However, the impact is more evident around BRT stations.
In terms of urban development, land-use conversion to commercial and mixed land use is observed. Moreover, new commercial development is also evident, which is consistent with our findings of analysis regarding land use transformation. According to interviewees, commercial activities have increased along the corridor as accessibility benefits provided by BRT and attracted new customers from other parts of Lahore that helped to stimulate economic activities and bring additional customers. At the same time, there are also a few small businesses (like convenience shops), that have experienced a decline in sales after the development of BRT. The development of BRT has divided the road whereas overhead pedestrian crossing is provided at specific locations. In response to the question about high-rise development and TOD, most of the interviewees indicated that the building regulations are strict, which do not encourage the development of high-rise buildings. Moreover, people also do not want to go for high-rise developments, first because of financial problems and secondly because they want to enjoy unrestricted ownership rights, which becomes problematic in case of multi-storey development. Lastly, development authorities have not prepared a plan for urban and economic development. In view of real estate agents, the government can promote TOD along the corridor by relaxing building regulations, providing incentives for development, relaxing tax for the construction industry, and restricting horizontal growth.

8.6 Summary

In this chapter, we have investigated the economic impacts corresponding to the development of Bus Rapid Transit (BRT). The economic impacts related to transit investment generally include its impacts on property values, inward investment, and extension of the labor market. The empirical evidence from Lahore has indicated that BRT has influenced the property values in its vicinity. Other factors related to property and neighborhood attribute also influence property values. Besides property value benefits, a substantial amount has been invested along the corridor after BRT development which also brings additional jobs. The interviews with investors and real estate agents indicated that BRT is one of the main factors for economic development along the corridor. Moreover, there exists a link between accessibility benefits provided by BRT economic and urban development. Interviews with real estate agents indicated that strict building regulations and financial issues are the reason that restrict high-density development. The government can encourage transit-oriented development by introducing new building regulations and providing financial packages to the developers.

9

Institutional Analysis

9.1 Introduction

Therewith we can conclude from empirical evidence that the BRT has impacts on its surroundings and vice versa. This chapter explores the role of various urban development and transport departments in pre and post BRT scenarios. Officials of the urban development and transport department were interviewed for this purpose. The interviews with officials indicated that amendments in building regulations were done to promote high-rise development in Lahore. Thus this chapter also presents an analysis of building regulations. Underneath are the departments that serve as intermediates with regards to transport and urban development.

9.2 Role of Urban Development Authorities

The Lahore Development Authority (LDA) and the Municipal Corporation are responsible for urban development in Lahore. Officials of these departments were interviewed to explore the role and responsibilities of development authorities before, during, and after the implementation of bus rapid transit (BRT). The interviews with officials of development authorities reveal that their role during BRT development was only limited to land acquisition. When discussed regarding the trend of urban development along the BRT corridor the response was consistent with the findings of our field surveys (see section 6.1). Officials indicated that Ichra, Shama, and Qartaba chowk are the main areas from where most of the redevelopment applications are submitted for approval. One of the reasons mentioned by interviewees was that these areas already have dense development patterns and less or no land is available for further development. The demand for additional areas stimulated by BRT has encouraged people to redevelop and go higher. Whereas, new development applications were received from areas likes Chungi-Amar Sidhu and Gajjumata where enough land is available for development. The officials expressed that they have not prepared plan to incorporate these transformations and promote transit orient development (TOD) along the corridor. Although an amendment in the Master Plan (development Plan) of Lahore was approved in 2015 but no special plan/guideline was proposed to promote TOD or high rise development along the BRT corridor. The sole purpose of this amendment was to convert agricultural land into residential land to promote the development of new housing schemes. In response to the question of why people do not get permission to make land-use transformations, the interviewee stated that the previous building and zoning regulations are too demanding. A setback (from plot-line to building line) of 30 feet is mandatory, which is not possible to attain on smaller sized plots. Thus, the building regulations restrict high-rise development.

The following constraints and opportunities for urban development were outlined by the interviewees:

Table 26 Constraints and Opportunities for Urban Development in Lahore

Constraints	Opportunities
The lengthy procedure of plan approval	A trend toward higher development
NOC from different departments (WASA, TEPA)	Better accessibility and infrastructure
Building and zoning regulations	Amendment in building & zoning regulations

According to interviewees, BRT is successful in providing people with better accessibility and reduced travel time. Furthermore, most of the officials of authorities recommended the need for new public spaces and TOD plan with special zones for commercial development. However, the question remains is that who will prepare these plans?
Since these first interviews were conducted in 2019, at that time local authorities were in the process of preparing the new building and zoning regulations (building codes). So, an extra set of interviews were conducted from the concerned official in relevance to the recent changes in building regulations.
The amendments in building regulations started when the Prime Minister of Pakistan initiated a plan to save prime agricultural land and promote high-rise development. The project started by identifying sites for high-rise development. Lahore Development Authority (LDA) took a leading role to complete this exercise with the following objectives:

- To promote high rise development/Grow vertically
- To enhance economy
- To fulfill housing needs
- To restrict urban sprawl
- To promote infill development
- To save prime agriculture land and,
- To promote environmental solutions

To initiate the process, LDA decided to review its building regulations by involving different professionals, academia, practitioners, and affiliated professional bodies. A committee including all these stakeholders was constituted to set the TOR (term of reference) of the project. A proposal regarding the amendment in building regulations was prepared and presented to stakeholders for their feedback. Lahore chamber of commerce, universities, and construction companies like NESPAK, were involved on an institutional level whereas electronic and social media platforms played the role in providing feedback from the general public. In this initial proposal, zoning is promoted based on floor area ratio (FAR), coverage, right of way, building height, and parking. Under this proposal, five categories with respect to vertical development are proposed (2 low-medium, 2 high, 1 sky scrapper) fragmenting Lahore into various patches to maintain the skyline. Moreover, new regulations will also encourage free conversion of residential plots into apartment buildings as the area requirement for apartment buildings is reduced from 4 kanal (18,000 sq. feet) to 10 Marla (2,250 sq. feet). The height of the apartment building would be maintained according to the location of the plot. For example, in a residential area, the height would be according to residential use and if it is located in a commercial zone, then the height will be allowed accordingly.

Along with these amendments, to encourage economic growth, a daily use shop in every apartment building has been declared necessary, and allowable building height for residential use is changed from 45 feet to 48 feet. These building regulations have been approved after negotiations with various stakeholders.

The zoning aspect is still incomplete. For the time being new zones e.g. with respect to height, road size, etc. are linked with previous zones (not properly declared as zones and fuzzy). In the future, authorities will study planning approval applications and market demand of specific land-use and will declare new zones. Moreover, before declaring new zones traffic and environmental impact studies will be performed. Authority may also have the power to revise building heights by observing changing development trends if deemed necessary.

Regarding Bus Rapid Transit (BRT) and Transit-Oriented Development (TOD), the officials expressed that our main focus is to promote high-rise development in whole Lahore rather than in any specific area. However, the BRT route is already in the high-rise development zone (with an allowable height of 200-300 feet) and if needed, they may allow unlimited height along the corridor in the future.

To further explore the changes in building and zoning regulations after the development of BRT and to investigate their relevance with regards to the BRT corridor, analysis of building and zoning regulations is presented in the next section.

9.3 Analysis of Building and Zoning Regulations

This section presents a comparison of building and zoning regulations between 2013 and 2021. Building and zoning regulation for three distinct land uses including residential, commercial, and apartment has been discussed. There has not been any major change in building codes for residential use. Also there is not a significant change in roles for mandatory open spaces, coverage area, and floor area ratio. Table 27 and Table 28 presents a comparison of mandatory open spaces, coverage area, and floor area ratio in case of a residential building. It can be seen that no change has been observed for mandatory open spaces for residential use between 2013 and 2020. Concerning ground coverage and floor area ratio a change has been observed for plot abutting the roads having right of way (ROW) 25 feet and above. In new regulations, the ground coverage for residential plots having areas less than 5 Marla (1125 sq. ft.) has been increased from 80% to 85%. Moreover, an amendment in the categorization of residential plots has also been observed. A new residential category of 10 Marla (2250 sq. ft.) to 1 Kanal (4500 sq. ft.) and 1 Kanal (4500 sq. ft.) to 30 Marla (6750 sq. ft.) has been introduced in building and zoning regulations currently being enforced. However, these changes in building regulation for residential use do not support multi-storey development; there has not been any change in building height for residential use in previous and prevailing building regulations.

Table 27 Comparison of required open spaces for residential use

Plot Size	2013			2020
	Building Line	**Rear Space**	**Side Space**	
Less than 5 Marla[1]	5 ft	Not required	Not required	Same as 2013
5 Marla's & above but less than 10 Marla	5 ft	5 ft	Not required	Same as 2013
10 Marla to 30 Marla	10 ft	7 ft	5 ft (on one side)	Same as 2013
Above 30 Marla but less than 2-Kanal[2]	10 ft	7 ft	5 ft (on both sides)	Same as 2013
2-Kanal & above	20 ft	10 ft	10 ft (on both sides)	Same as 2013

1) 1 MARLA = 225 SQUARE FOOT

2) 1 KANAL = 4500 SQUARE FOOT

Table 28 Comparison of ground coverage and FAR for residential use

		Plot Size	**Less than 5 Marla**	**5-10 Marla's**	**10-30 Marla's**	**30 Marla – 2 Kanals**	**2-Kanals & above**	
2013	ROW* up-to 25 ft	Max. ground coverage	85%	80%	70%	65%	60%	
		Max. FAR	1:2	1:1.6	1:1.5	1:1.4	1:1.3	
	ROW more than 25 ft	Max. ground coverage	80%	75%	70%	65%	60%	
		Max. FAR	1:2.4	1:2.3	1:2.8	1:2.6	1:2.4	
2020		Plot Size	**Less than 5 Marla**	**5-10 Marla's**	**10 marlas – 1 Kanals**	**1- 2 Kanals**	**2-Kanals & above**	
	ROW up-to 25 ft	Max. ground coverage	85%	80%	70%	65%	60%	
		Max. FAR	1:2	1:1.6	1:1.5	1:1.4	1:1.3	
		Plot Size	**Less than 5 Marla**	**5-10 Marla**	**10- 1 Kanal**	**1 Kanal to 30 Marla**	**30 Marla – 2 Kanal**	**2 Kanal and above**
	ROW more than 25 ft	Max. ground coverage	85%	75%	70%	65%	60%	55%
		Max. FAR	1:2.4	1:2.3	1:2.8	1:2.6	1:2.4	1:2.2

*Row = Right of Way

The analysis of building regulations reveals that a significant change has been made in regulations for the development of apartment buildings. In 2013, an apartment building (on residential plots) was only allowed for plots measuring area 4 Kanal (18,000 sq.ft.) or above whereas in the new regulations an apartment building can be built on a plot size 10 marla (2,250sq. ft.) In accordance with new regulations mandatory open spaces have also been reduced. Table 29 presents a comparison of mandatory open spaces for apartment buildings. It is evident from the table, that compared to 2013, the requirement of open spaces has been relaxed. Previously, for all apartment buildings a setback[3] of 30 ft. was mandatory which now has been reduced to 10 feet for plot up to 2 kanals. Different height zones (low-rise to skyscraper) have been defined for apartments that were not part of the previous regulations. The height zones are defined based on plot size and ROW of the abutting road as shown in Table 30.

3) OPEN SPACE BETWEEN BUILDING LINE AND PROPERTY LINE

Table 29 Comparison of mandatory open spaces for apartment buildings

	Plot Size/zone	Building Line	Rear Space	Side Space
2013	All apartment buildings	30 ft.	13 ft.	13 ft. on both sides
2020	10 Marla to 30 Marla	10 ft.	7 ft.	5 ft. on one side
	Above 30 marla but less than 2 Kanals	10 ft.	7 ft.	5 ft. on both sides
	2 Kanal & above	30 ft.	13 ft.	13 ft. on both sides

Table 30 Height zones for apartment buildings

Zones	Plot Size	Storey	Height	ROW of road
Low Rise	Min 10 Marla to less than 1 Kanal	Ground + 3	Up-to 48 ft.	Min. 30 ft.
Medium Rise-1	Min 1 Kanal and less than 2 Kanal	Ground + 6	Up-to 90 ft.	Min. 40 ft.
Medium Rise-2	Min 2 Kanal and less than 4 Kanal	Ground + 11	Up-to 160 ft.	Min. 40 ft.
High Rise-1	Min 4 Kanal and less than 8 Kanal	Ground + 14	Up-to 200 ft.	Min. 60 ft.
High Rise-2	Min 8 Kanal and less than 12 Kanal	Ground + 23	Up-to 300 ft.	Min. 80 ft.
Skyscraper	Min 12 Kanal and above	No restriction*	Above 300 ft.	Min. 80 ft.

* No objection certificate from Civil Aviation Authority

Building and zoning regulations have also been amended for commercial use. In Lahore commercial use is divided into 5 categories.

1. Central Business District
2. Main Civic and Commercial Center
3. Neighborhood Commercial areas
4. Other Commercial areas
5. Converted Plots

In 2013, the following rule was applicable to define the height of the building in the[8] central business district, and on converted plots.

Building Heifht = (ROW x 1.5) + Setback

However, in the new provisions, new heights have been defined for commercial use in the central business district, other commercial and converted plots as shown in Table 31.

Table 31 Height zones for commercial use

Zones	Plot Size	Storey	Height	ROW of road
Low Rise	Min 10 Marla to less than 1 Kanal	Ground + 3	Up-to 50 ft.	Min. 30 ft.
Medium Rise-1	Min 1 Kanal and less than 2 Kanal	Ground + 6	Up-to 90 ft.	Min. 30 ft.
Medium Rise-2	Min 2 Kanal and less than 4 Kanal	Ground + 9	Up-to 120 ft.	Min. 40 ft.
High Rise-1	Min 4 Kanal and less than 6 Kanal	Ground + 14	Up-to 200 ft.	Min. 60 ft.
High Rise-2	Min 6 Kanal and less than 12 Kanal	Ground + 23	Up-to 300 ft.	Min. 80 ft.
Skyscraper	Min 12 Kanal and above	No restriction*	Above 300 ft.	Min. 80 ft.

*No objection certificate from Civil Aviation Authority

Likewise, height zones have also been introduced for the main civic center and neighborhood commercial areas. Yet, concerning our study area (BRT corridor) the confusion still prevails. There are two development authorities exercising development control along the BRT corridor. So, any case for high-rise commercial development is sent to the high-level design committee (HLDC) which is comprised of the following members:

- District coordination officer, Lahore Chairman
- Representative of Zila Nazim member
- Town Nazim or his representative member
- District police officer, Lahore member

- Director general, LDA member
- Director housing & physical planning dept. member
- Chief architect, C&W department member
- Chief traffic engineer, TEPA, Lahore member
- Director EPA government of Punjab member
- Executive district officer (W&S) Lahore member
- *Executive district officer (MS) Lahore member*

Additionally, there are specific areas along the BRT corridor like Gulberg that have their own building regulations.

9.4 Role of Transport Agencies

There are various actors that are responsible for the planning, development, operations, and maintenance of transport services in Lahore (see chapter 5 for details). Interviews with officials of these different transport departments were performed for the purpose of this research i.e., to investigate their role in the development of bus rapid transit (BRT) and how their role and responsibilities have changed over-time. Officials from Lahore transport company, traffic engineering and transport planning agency, transport planning unit, and Punjab mass-transit authority were interviewed.

9.4.1 Role of Lahore Transport Company (LTC)

Interviews with officials of Lahore transport company (LTC) reveal that they are responsible to give road permits to buses, wagons, and rickshaws in Lahore. The initial project tendering work was performed by LTC. They also provide 70-80% subsidies to private operators to run public transport. According to the officials, about 20% of mobility needs are fulfilled by public transport. The responsibilities of LTC are already described in section 0. However, according to officials, their responsibilities and jurisdiction have changed the opening of BRT. A new transport authority with the name of PMA was established, which received the responsibility to issue route permits along the BRT corridor. At the moment, LTC is responsible for the public transport operations in Lahore and does not perform any duty related to transport operations along the BRT corridor anymore. Moreover, after the development of BRT, public transport routes along the BRT corridor were restricted and alternative routes were provided to encourage a modal shift to BRT. PMA is instructed to integrate BRT service with other public transport services. This decision of shifting responsibilities was just for political gain. Likewise, overall working of LTC was restricted, which has also affected the mechanisms for subsidies. The officials highlight that, although PMA is only providing services along the corridor, still they have more resources than LTC due to which LTC is facing financial problems. When asked about the possibility to upgrade BRT system in near future, the officials indicated that the bus frequencies could be increased. However, the BRT service cannot be upgraded to LRT because of the lower bearing capacity of the present infrastructure. They also added that currently, the system is under-utilized, and low parking fees can be introduced to enhance the mode shift. When inquired about transit-oriented development, it was their view that this is mainly the task of the urban development authorities, such as the Lahore development authority. When asked about how they coordinate with other transport and urban development departments, the officials responded that there is no or weak coordination between departments. Furthermore, they added that if they want to execute any plan in Lahore they only inform other departments through an official letter. In view of the officials, BRT is performing quite well and is successful in promoting economic growth which has also created new jobs. Nevertheless, the corridor has a lot of potential for future economic and urban growth, and urban development authorities should use this potential to promote sustainable development around BRT.

9.4.2 Role of Traffic Engineering and Transport Planning Agency (TEPA)

The traffic engineering and transport planning agency (TEPA) is responsible to resolve traffic-related issues, particularly concerning road infrastructure, traffic control, and ITS technologies. TEPA helped Japan international cooperation agency (JICA) with the preparation of the first transport master plan for Lahore in 1991. Similarly, TEPA played an important role in Lahore urban transport master plan (LUTMP) 2012. The interviewed official also indicated that the introduction of park and ride facilities along BRT was one of the initiatives introduced by TEPA. Like LTC, some of their responsibilities have also been transferred to Punjab Masstransit Authority (PMA) after the operation of BRT. When asked about how is TEPA responsible to integrate transport and urban development, the Interviewee suggested that it is the responsibility of urban development wing of Lahore development authority (LDA) to prepare to encourage integration between transport and urban development. It was further added that BRT corridor has a lot of potentials for urban development moreover, BRT has provided customers with improved accessibility. Therefore, the urban development department should allow the construction of multi-storey buildings and give tax relaxation for economic development. The interviewee also mentioned that they have a plan to extend BRT service in both directions.

9.4.3 Role of Punjab Masstransit Authority (PMA)

Punjab masstransit authority (PMA) is of particular importance as this is one of the departments specially established to develop, control, monitor, and maintain masstransit services in Punjab including BRT Lahore. Besides, PMA also plans and operates integrated public transport routes (feeder routes). Therefore officials of PMA have been interviewed to explore their role and responsibilities. According to officials of PMA, they have outsourced the operation and maintenance of BRT to tap the efficiency of the private sector. BRT is operating well, however, the fare is fixed by the government for political gains (to take votes). The operating cost of BRT is high but revenue is low due to fixed fares so PMA has to give subsidies to the private operator because of which most of the PMA's budget is used for subsidies. There is a need to raise the fare in order to enhance the service. In response to the question of whether PMA has any plan to extend BRT services, officials indicated that they have plans to extend BRT service 10km toward the north (Shahdhara-Kala Shah Kaku) and 5km towards the south (from Gajjumata-Kahna). In view of the interviewee worldwide trend shows high-rise development along transit corridors and therefore, in our case, Lahore Development Authority (LDA) and the government should take action to promote this kind of urban development along the corridor, in order to capitalize on the external benefits of BRT investment and achieve the goal of sustainable development. When inquired about economic growth, officials described that corridor has a lot of potentials but is in need of serious actions from the responsible urban development authorities in this regard. Moreover, tax relaxation by the government can promote investment along the corridor and more jobs can be created along the corridor, they added.

9.5 Summary

The institutional analysis indicated that there is not a uniform urban development policy along the BRT corridor. Moreover, the involvement of different stakeholders further complicates the situation. There is a number of departments/agencies working for transport and urban development in Lahore with little or no collaboration. The deficiency of cooperation between these departments and the lack of political interest are the reasons that compact urban development remained irrelevant. Thus there is a need to improve coordination between urban development and transport departments for integrated urban development. Generally, a review of the building regulations indicated that efforts have been made to promote high-rise development in Lahore. The interviews with the officials of development authorities specified that the link between transport and urban development is not being focused in new building regulation. In Lahore, there is a need to emphasize BRT stops/stations as the major nodes for urban development. This would certainly help to establish the missing link between transport and urban development.

10

Conclusions & Recommendations

10.1 Introduction

This dissertation started from the observation that cities around the world are facing numerous problems relating to transport such as environmental degradation, congestion, travel delays, air and noise pollution, road accidents, etc. These problems are the consequences of prompt growth in motorization and amplify dependency on personal vehicles. Governments are spending a huge amount of their resources to shift travelers to more sustainable and green modes of transport. Subsequently, Bus Rapid Transit (BRT) has gained popularity worldwide, especially in underdeveloped countries because of its cost-effectiveness and ability to fulfill mobility needs. Envisaging its benefits, BRT has become increasingly appealing in various Asian cities with major traffic jams, especially in those having budget constraints. Since the majority of BRT systems are relatively new, empirical evidence to assertion their impacts on travel behavior, urban development, and the economy is insufficient. There are mainly three major concerns related to this subject. First, inadequate research on BRT from the perspective of users is evident. This is crucial because the social benefits provided are the principal justification for BRT investment. Secondly, public transport investment is generally perceived by planners as a pure and exclusive mobility investment strategy and city-shaping impacts of BRT are mostly being ignored. Thirdly, accessibility benefits provided by transit investment are capitalized into higher land values. It is indispensable to quantify the land/property value effect of transport investment for evaluating whether a land value capture technique is feasible or not in a specific geographical context. To enhance our knowledge in this respect and to fill this research gap, this dissertation examines the external benefits of BRT and attempts to quantify the travel behavior, urban development, and economic impacts of BRT. This study focuses on the case of BRT in Lahore, as a representative of developing countries and more specifically of South-Asia.

10.2 Review of Findings

The main research questions of this dissertation are.

a. What are the impacts of BRT on people's travel behavior?

The second impact category corresponds to the travel behavior impacts of BRT. The impacts of BRT on people's travel behavior and the factors affecting mode choice between BRT and other modes of transport are assessed using binary logistic regression. The results of the analysis show that BRT-Lahore has substantial impacts on the travel behavior of travelers. Besides mode shift, BRT has also improved the choices for more environmentally friendly modes of transport, like walking. As most of the countries turning toward more sustainable modes of transport. Likewise, the modal split for sustainable modes such as walking and cycling can be improved by introducing bicycle lanes and improving sidewalks. It is further revealed that travelers' characteristics such as age, gender, occupation, education, and income significantly influence the mode shift to BRT. Moreover, individuals with an age of fewer than 30 years are more probable to select BRT as their mode of travel, compared to other age groups. This is possibly also because BRT-Lahore is operating in the middle lane of the corridor and on most of the station's pedestrians have to take stairs to reach BRT station. Generally, elevator access is not provided for or when in some cases elevators are installed, they are often not working properly. Restricted access instigated by build environment constrains elderly people to the use of public transit system (Park, Chowdhury, & Wilson, 2020) which is perhaps one of the reasons that hinder the elderly and disabled people to choose BRT in Lahore. The analysis reveals that male has more probability to choose BRT. Sexual harassment can be one of the reasons that prevent women from using BRT. Separate ticketing booths, waiting and seating areas at station areas can help to produce a safer environment for women. Similarly, household income influences the choice of travelers in Lahore. In general, with an increase in household income the probability to choose BRT as a mode of transport decreases. Trip characteristics including travel purposes and vehicle ownership also influence the travel mode of choice. Thus there is a need for measures like road pricing and congestion charging to make BRT work effectively.

The analysis of service-related attributes of BRT (e.g. time, costs, safety, reliability, comfort, integration) indicates that travel time, travel cost, and safety are the most important factors to influence the choice for BRT. Since the travel time and the travel cost has been deduced as the most significant service attributes for mode choice during binary logistic regression, further performance analysis (e.g. ANOVA) was performed to compare the mean change in travel time and travel cost. A substantial difference was observed for the mean change in travel time. In this respect, BRT users have less travel time compared to an individual using a car, motorcycle, rickshaw, or other modes of transport. Also, a difference in mean change in travel cost was observed between BRT and car users. The same goes for (travel & gender) safety. But measures like awareness campaigns and free rides coupled with road pricing are needed to promote BRT as a preferred mobility alternative for Lahore because it is cheaper, faster, and safer compared to other modes of transport. Therewith we can conclude that BRT in Lahore has substantially influenced the travel pattern of people. But we still need to adopt new policies such as road pricing and parking tickets to promote sustainable modes of transport like BRT and to curb private vehicle use.

b. What are the impacts of BRT on urban development?

The empirical evidence exploring urban development patterns in Lahore indicated that BRT has the potential to stimulate land-use transformation. However, the extent of transformation is context-dependent; thus relational. All the assessed BRT stations have shown an increase in commercial activities due to land-use conversion. But the extent of transition varies across the entire corridor. It depends on the distance to the BRT station, the width of the road, land use policy, and local conditions. Furthermore, change in population and building density is also evident in the study area. Population density has increased from 268 persons/acre to 299 persons/acre. An increase in building density for residential and commercial uses is observed majorly for all stations. In comparison to general development patterns in Lahore, areas around BRT have become increasingly appealing for residential and commercial activities. People living in the vicinity of BRT stations are fulfilling their housing needs by densifying vertically in cases where less or no land is available for new development. But development authorities have not introduced any land-use policy to streamline urban development.

Next to that, the accessibility benefits provided by BRT and boosted land market has also encouraged people to build higher, resulting in higher vertical density. Thus, the observed land-use transformations and new activities indicate that BRT in Lahore is somehow successful in encouraging land-use transformation in its vicinity and that these benefits can be catered in an efficient way for the creation of a compact urban neighborhood. But these are not focused in new building regulations and no plan has been outlined to integrate transport and urban development. as a result the development along the corridor may turn chaotic. Although the urban development trends were also identified by local authorities and real estate agents, no real action has been taken to promote sustainable development.
Lastly, it can also be observed that areas around the BRT station in Lahore have the potential for further land-use transformation. But it highly depends on the availability of land, activities of investors, and policies of urban development departments.

c. What are the economic impacts of BRT?
The economic impacts are related to the third type of BRT impact being investigated in this dissertation. Economic impacts mainly cover BRT impacts on property values, inward investment, and extension of the labor market. This dissertation explores the property value impacts of BRT in Lahore and specifically focuses on the spatial distribution of these impacts using geographically weighted regression (GWR). Identifying the spatial distribution of land value uplift is of significance from the perspective of policymakers as it can help in underpinning equity consideration for tax enforcement. The hedonic pricing model (HPM) and GWR model is developed to investigate the relationship between property values and various independent variables (e.g. property attributes, neighborhood attributes, and accessibility). The hedonic model, as a global model, provides the average impacts of independent variables on property value, whereas GWR as a local model provides the opportunity to explore and map the local variations in property value premium.

The results of the HPM indicate that the physical characteristics of the property building age and number of bedrooms are significantly associated with an increase in property value. But it is highly related to the width of the road as a neighborhood attribute and the proximity towards BRT stations. The proximity to the BRT station has significantly influenced the property values in Lahore. The investments in BRT have almost doubled the property values in its surrounding areas.
However, HPM does not provide local variability in property prices therefore, the application of GWR helps to better understand variation in property values. The mapping of local parameter estimates for proximity to BRT station shows a significant association between property value and proximity to BRT station over the entire length of the BRT corridor. However, properties located in the north within 500 meters of Shahdara, Timber Market, and Qartaba chowk station gained a higher premium compared to properties located around other BRT stations. Therewith the areas with an increase in property values could be focused to implement property value capture technique. This could serve as a source to fund other projects.
Even when the relationship between property value and other accessibility variables are non-significant the properties located near the north terminal of BRT gained a higher premium. Overall for the entire corridor, a decline in the distance to the BRT station

is associated with an increase in property value and the value of premium varies over the entire BRT corridor. The evidence from BRT-Lahore concerning inward investment indicated that an increase in economic activities is also witnessed along the corridor. Almost 22,000 million rupees (US $140 million) inward investment is detected after the implementation of BRT, which ultimately brought around 800 new employees from remote areas.

Therewith we come to our main question: ***How does investment in Bus Rapid Transit (BRT) impacts travel behavior, urban development, and economy?***

Concerning these questions, we can conclude that BRT, Lahore has a significant impact on its neighboring areas in terms of travel behavior, urban development, and economy. BRT is successful in generating land development and economic activities in its surrounding areas. A huge volume of daily passengers also indicates its impact on the travel behavior of people. However, these impacts are highly context-dependent, thus relational, therefore, we need to go beyond this to investigate the interrelation between these impacts. how these impacts.

Therewith we come to our research question: ***How are travel behavior, urban development, and economic impacts related to each other?***

Interviews from property owners, investors, real estate agents, and officials from the transport and urban development department were used to identify the association between different impacts of BRT and to answer the research question. This inter-relation can be put down in the form of a pictorial diagram (see Figure 94).

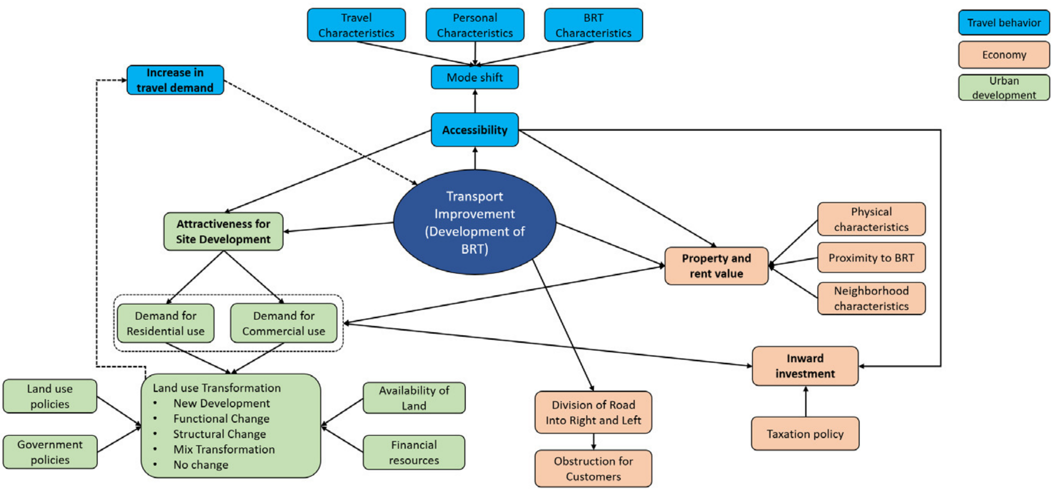


Figure 94 Interrelation between impacts of BRT

The interrelations between travel behavior, urban development, and economy described here are extracted from Figure 81, Figure 92, and Figure 93. The development of BRT has improved the accessibility to different places in the city that trigger a modal shift to BRT. In addition, improved accessibility resulting from BRT has also influenced the urban development and economic parameters, and vice versa. Now the areas around BRT, Lahore have become more attractive for residential and commercial development. This demand for residential and commercial use is mainly influenced by improved accessibility and transport improvement. The demand for new uses has encouraged people toward land use transformation. The urban development and transport impacts further trigger economic impacts. Improved accessibility resulting from BRT development also has a direct relation with higher property values. Similarly, the increased demand for certain land uses has influenced the property values and also brought inward investment in the areas served by BRT. Conversely, the economic impact of BRT has also influenced the urban development patterns in Lahore. The areas around BRT have become attractive for urban development as property and rent value upsurges. In specific areas investment in apartment buildings is induced by economic benefits; investors can earn by renting their place at higher prices.

Therewith the association between different impacts of BRT is of ***complex nature*** since there are a lot of dynamic external factors involved. The interrelation between transportation, urban development, and economic development is continually adapting (see Figure 95) and every sub-system co-evolving with each other in a spatial geographical context (for the good or the bad). The development of any transportation system influences different aspects of urban and economic development and vice versa. Future high-rise development and economic development along BRT might induce new demand for an improved or new transport service but is highly dependet on future land use and transport policies. This interrelation between transport, urban development, and economy can be explained through the actor relational approach (ARA). According to this, the interrelation between different actors in a specific dynamic setting affects the conscious actors and locatable dynamic settings which further drives change. Hence, agencies and institutions co-evolve and they are never closed rather they are continuously in the state of becoming and thus always in a condition of innovation.

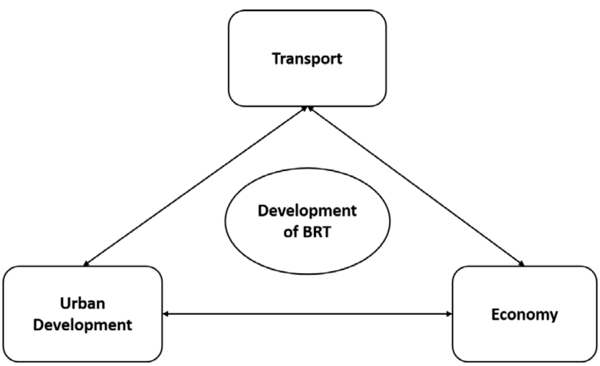


Figure 95 Transport, urban development and economy feedback cycle

As described earlier agencies and institutions co-evolve and always in a state of becoming. Therewith there is also a need to adapt urban-infrastructure policies and the institutions involved to promote sustainable urban growth. This brings us to our next research question: ***How do different institutions, actors, and factors evolve and interact with each other for the development of BRT?***

The interviews with concerned actors revealed that main development activities during construction of bus rapid transit (BRT) were managed by transport authority (e.g. traffic engineering and transport planning agency) whereas, development authorities including Lahore development authority (LDA) and municipal corporation only assisted with land acquisition. There has not been much change in the role and responsibilities of development authorities after the BRT operation. In order to manage the BRT operation and maintenance matters sufficiently in Lahore and the whole of Punjab in general; a new organization named Punjab Masstransit Authority (PMA) is established. The introduction of PMA has altered the role and responsibilities of the transport-related organizations including Lahore Transport Company (LTC) and Traffic Engineering and Planning Agency (TEPA). Now PMA has the responsibility to manage feeder routes and other public transport services along the BRT corridor which were previously managed by LTC. Although these initiatives have played their role in the success of BRT, they also disturb the performance of LTC in other parts of Lahore. LTC is struggling in providing public transport services due to budget constraints.

The institutional analysis elaborated that there has been no policy to integrate transport and urban development along the BRT corridor. Thus, the question of integrating transport and land-use remains. Although a high-rise development policy has recently been implemented in Lahore under which all the areas are opened for high-rise development. It is too early to say something about this but the new policy would generate demand for new infrastructure. Given the limited financial resources, it would be difficult to fulfill infrastructure demand in the whole city.

Therefore, there is a need to focus on the specific areas that have the potential for high-rise development in Lahore. The evidence presented in this dissertation has shown that areas around BRT stations have the potential and can be utilized as focal points for high-rise and high-density development. This leads us to our last research question and important policy recommendation that corresponds to prospects of transit-oriented development (TOD) in developing countries. TOD focuses on the integration of transport and urban development for the creation of sustainable neighborhoods. The major barriers to TOD have been identified through field surveys, interviews with different actors, and analysis of building and zoning regulations. Therewith we can now come to our final question: ***What are the barriers to Transit-Oriented Development? and How to leverage Transit-Oriented Development (TOD) in developing countries to maximize the benefits of BRT investment?***

Transit-oriented development (TOD) has been recognized as an efficient urban policy to enhance accessibility and urban development patterns by establishing a strong affiliation between transport and urban development. But In Lahore, Pakistan there exists numerous barriers to achieve TOD. There are several departments/agencies working for transport and land use development with overlapping jurisdictions. Moreover, there exists poor coordination between these actors (actors related to transport and land use) which often results in negative spillovers and inefficiencies. It is the result of poor coordination between departments and lack of political support that no TOD plan has been prepared. In order to establish TOD, several actors and agencies needed to coordinate with one agency taking the leading role. In Lahore, as elsewhere in developing countries this leading authority is still missing. Besides absent of supportive infrastructure for pedestrian also influence the BRT ridership. These barriers needed to be overcome if we want transit investment to shape urban areas significantly. The condition in most developing countries is not different from what is observed in Lahore. In these countries, the integration between transport and urban development is mostly being ignored while planning. BRT in Ahmadabad, India is another example of poor integration between transport and urban development. The city-making benefits of BRT could not be capitalized on because of the absence of an integrated policy. The results of this research and policy framework proposed hereafter could be translated for other developing cities to encourage sustainable development.

Consequently, we have proposed a framework (see Figure 96) for practitioners in the context of Lahore to stimulate transit-oriented development (TOD). The measures to promote TOD have been identified by exploring worldwide best practices. Subsequently, these measures were translated and proposed in the context of Lahore through quantitive analysis done in this research and interviews with all the stakeholders including residents, development and transport authorities. The purpose of this relational framework is to integrate transport, urban development, and economic activities along the BRT corridor to establish the basic principles of TOD. First of all, there is a need to revamp the role of development and transport authority in the context of TOD. In the present fragment structure where responsibilities are distributed between different actors, Lahore Development Authority (LDA) is responsible for delineating development policies and should take the leading role in the planning and execution of the TOD plan. Strong political support to execute the TOD plan could play an important role in this regard. Moreover, there is a need to enhance the coordination between the transport and urban development departments. In this respect urban and transport planners needed to act proactively to integrate the external benefits of BRT. Besides, the TOD plan should be supplemented by a redevelopment plan especially focusing on old developed areas like Ichra, Shama, and Bhatti chowk.

Building and zoning regulations should be amended to encourage high-rise development. Higher density can accommodate new dwellings, which would help to counter urban sprawl in Lahore. BRT stations can be promoted as places for high-rise development and density tapering as moving away from BRT. Stations like Ichra, Kalma Chowk, and Timber Market can be encouraged as multifunctional nodes. Whereas, a station like Yohanabad can be promoted for high-rise residential development. Secondly, although BRT investments are relatively low, they also require high ridership. Following the famous saying “mass transit needs mass”, there is a need for density bonuses and an increase in floor-area ratio to generate high ridership for BRT. Higher density can be promoted by introducing tax exemption schemes, assisting land assembly, and relaxing parking requirements in the central areas. High-rise development could also enhance the use of private vehicles therefore, measures like road pricing and congestion charging might help to hamper the use of private vehicles and attain a higher BRT ridership. Policies encouraging land assembly could help in generating new development opportunities and a window for public-private partnerships.

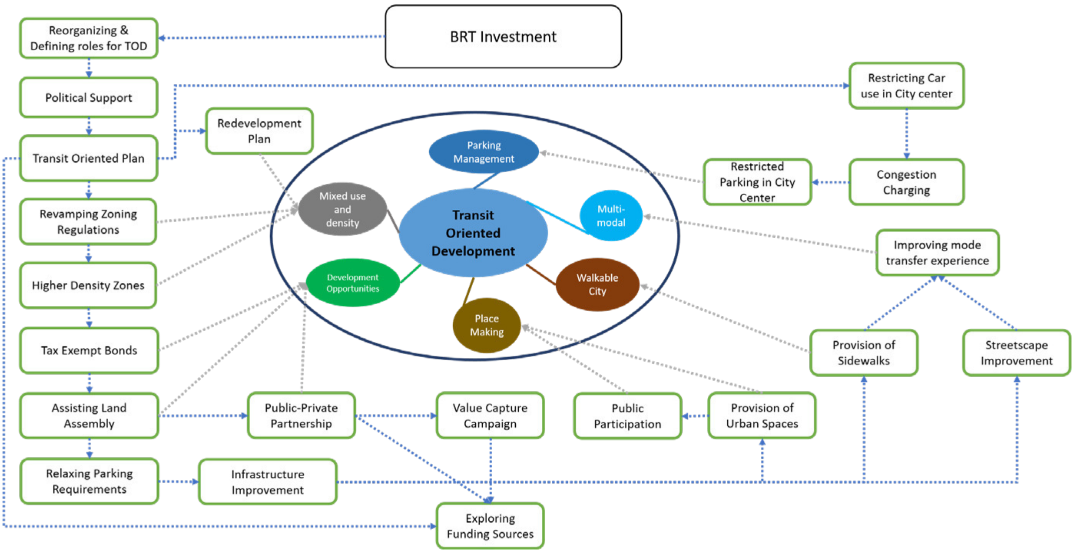


Figure 96 Framework to promote transit oriented development in Lahore

Nevertheless, along with density bonuses, there would be a need to upgrade supportive infrastructure. In order to attain sustainable urban development, high-density development should be supported by BRT. Therefore, it is recommended to ensure good accessibility to the BRT stations. Moreover, the urban landscape be enriched by improving streetscape and sidewalks. Besides integrating transport and land use development, the integration of BRT with other modes of transport is also another important aspect. A good network of sidewalks and attractive street landscape would help to achieve the objective of a walkable city and could increase multi-mode travel. The provision of parking spaces at BRT terminals along with congestion charging in the central business district can induce a modal shift to BRT. Though this is not an easy task, encouraging public participation can help to achieve the goal of more sustainable transportation. Along with congestion charging a reduction in on-street parking or expensive parking in the city center can also play an important role in this regard.

Place-making is an important aspect of TOD that provides people with an experience to socially interact which is absent along the corridor. Therefore, in the TOD plan, there is a need to design urban spaces along the corridor.

Last but not the least, financial obstacles are of major importance when implementing TOD plans. In the case of Lahore, two sources could be used to generate financial resources. First public-private partnership during land assembly can help to generate additional resources. Secondly, a land value capture policy can be utilized for this purpose. Betterment tax is one of the best techniques adopted by the United Kingdom (UK), Colombia, and India (Walters, 2013). The empirical findings have indicated a spatial variation in BRT impacts on property values suggesting that a uniform betterment tax would not be a good option to implement. Moreover, it's only been eight years since BRT has started its operation and the property value benefits arising from BRT are still not enough to endorse a land value capture policy. The relationship between transit investment and amplified property value is more apparent over time. So, a land value capture technique can be implemented in the future.

Concluding the discussion, it is recommended that the findings of this study should be considered before implementing other transit systems in Lahore that are delineated in the Lahore Urban Transport Master Plan (LUTMP). A number of barriers needed to be dealt with if future BRT/transit investments are to successfully shape the urban environment in developing countries around the world. Integration between transport investment and land-use policies can play a decisive role in realizing compact and sustainable neighborhoods. Therewith the findings of this research could be useful for the planning of BRT systems in other Asian cities and to ensure higher BRT shares in Lahore.

In a broader spectrum, transport investment also influences social and environmental aspects which have not been considered in this dissertation. Consequently, research particularly focusing on the social and environmental benefits of BRT is recommended. An increase in rent and property values that have been observed in Lahore might have triggered social exclusion i.e., migration of low-income people from areas around BRT due to high rent which still needs to be explored. Secondly, a study investigating air quality, noise pollution, CO_2, and PM emission can help to understand the impacts of BRT on the environment. Moreover, three other BRT systems are already in operation in Pakistan however, no study has been carried out to explore the external benefits coupled with these systems. Thus, there is a need to explore the impacts of these systems on neighboring areas, this could be done through the application of the actor-relational approach. Lastly, during this studied there has been a major change in building regulations that could not be dealt with in this study, thus a study focusing on the impacts of these regulations on development patterns is recommended in the future.

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ANNEX-A
INTERVIEW SCRIPT-RESIDENTS

Interview questions

1. What changes you have made in your building after the development of BRT?
2. If none then why did not you make any change?
3. Are you expecting to make any change in the near future?
4. Why did you make these changes?
5. If this change is due to BRT then what are the impacts of BRT on your property?
6. What is the reason /what makes you think that you should make the land-use change?
7. Did you take permission from the competent authority to make a structure or land-use change?
8. What obstruction did you face while making changes in your building?

R-1

I have done redevelopment because some portion of my property was demolished as it falls under the road during extension of the road for BRT development. In the future, I am expecting to add more storeys as I can earn by renting out the additional space. BRT is the reason for redevelopment moreover, now I can also earn money by renting additional floor/space. An increase in property values is one of the impacts associated with BRT which makes this place more attractive for people and provides properties with better accessibility. Now I have rented my upper portion easily. No, I did not ask permission from the local development authority before redevelopment. Yes, I was facing financial obstructions and other than this I have not faced any problem.

R-2

I have not made any change in the building because I am with our current resident and do not need any change. I am not expecting to make any change in the near future.

R-3

Previously the property was only under residential use now I am using the ground for commercial activity and using the upper floor as residential (land use changed from residential to residential/commercial). No, I do not want to make any change in the future. Due to BRT road width has increased and BRT has brought new business opportunities so I have converted my plot to commercial use. BRT has made this place more attractive by providing better accessibility which in turn has positively affected the property prices. Changing property from residential to commercial has become a source of income for me. Seeing the market trend I thought it could be a source of income. Yes, I took permission from the authority. It is a really tricky process to convert the land use of the property and getting design approval from the authority

R-4

I have carried out redevelopment activity at my property with the addition of one room. No, I do not want to make any change in the near future. Maybe I will think about it in 5-10 years. I needed additional space at my place: I have not made this change due to BRT but BRT has influenced the property value positively. No, I did not take any permission from the authority. I did not feel any obstruction.

R-5

I have not made any changes to my building. Although we need additional space but I could not make any change due to financial problems. Yes, in coming years I would like to add one storey to the current structure of the building but for this, I would need to gather finances.

R-6

I have redeveloped my building and added a new storey to my house (mix development). No, I have not any plan to make any further change in the near future. There was much demand for new houses in my vicinity so I thought to add new storey which was not possible on the previous structure so I build it again with new storey addition so that I can earn money by renting my upper floor. people from different areas like Sheikupura come here in search of a job and they mostly rent a place here in this area. BRT influenced life in every aspect by improving accessibility and people are now interested to live in the areas nearby BRT. Value of land has also gone higher which also increased the rent in these areas. New earning opportunities have opened after BRT. No, I did not sick any permission from the local authority for redevelopment. Yes, there were people from municipal administration who were visiting here quite often and they make a lot of hurdles during construction.

R-7

No, I did not make any change. We are only 2 persons living here in this place which is sufficient for use so do not need any change. No, I have not any plan to make any change in the future.

R-8

One storey was built onto the existing structure when BRT development started. No, I do not want to build my house again. There was a dire need for additional space as my son got married so put constructed another storey. This place is more attractive for new dwellers with better accessibility. property prices have also increased. No have not got permission to make a change in the property. I don't know about this. It was difficult to manage financial resources to build.

R-9

No, change made in the building. Do not have financial resources to construct further or make any change. Yes, I would like to add one storey and would convert the ground floor into commercial use.

R-10

I rebuilt my house and condition of building was not good. No, change is expected in the near future. The condition of the building was not good so I rebuild my house. The value of my property has increased because accessibility to this place has improved after the development of BRT and people are now more interested to live in the vicinity of BRT. Yes, I took permission from LDA. I faced financial problem during redevelopment.

R-11

No change made in the house. I have financial problems. In future, I will add more storeys to the existing structure.

R-12

Redeveloped my house and gone higher as added more storeys after redevelopment (mix development). No in near future not expected to make further changes. Firstly, I needed additional space and BRT development was added value so I make more space in my house to rent it out. Now I have rented out the top portion of my house on higher rent. BRT has improved accessibility. Land prices have increased after BRT development. No permission was obtained. No, I have not faced any problem while construction.

R-13

I have added a new storey to my current building. No in near future not expected to make further changes. I have made this change due to BRT, to earn money by renting an additional floor. BRT give people easy access along Ferozepur road that's why high demand along BRT. BRT has improved accessibility. The place is now more attractive for new dwellers. Increase in property value. Now I have an additional income of 20-25 thousand from the rent of the additional floor. No have not taken permission. No obstruction was faced.

R-14

Previously this building was used as residential property only now lower floor has been converted to commercial use (land-use conversion from residential to residential/ commercial). No, do not need any construction activity in foreseeable future. I have made changes due to BRT, to earn money by renting the lower floor for commercial use as there is a high demand for commercial uses. BRT has improved accessibility. This place has become more attractive for new dwellers. Increase in property value. Additional income from renting. As there is a high demand for commercial uses so the demand of the area forces me to take this step. No permission attained from the local authority. I face some financial problems and hurdles from the TMA as well.

R-15

The property was redeveloped after BRT and with redevelopment land use of the property was also converted from residential-only to residential/commercial. (lower floor for commercial and upper for residence). No expected to construct again in future. The development of BRT is one of the reasons for this redevelopment and land-use change. Property face the main road and commercial activities are prevalent in this area. The property has two access (corner plot) which make it more suitable for commercial and residential activities. BRT has improved accessibility. This place has become more attractive for new dwellers. Increase in property value. The property is facing the main road which gives us the opportunity to convert this plot. Yes, permission was obtained before redevelopment. I faced financial problems while transformation.

R-16

No change is made to the property. No need for any alteration in the home. I do not have any plan to make changes.

R-17

Previously the property was used for residence now currently we have an office (land use changed from residential to the office). No change is needed in future. The development of BRT is one of the reasons for land-use change. mostly there are office building in the vicinity so land use has changed. A good source of additional income. BRT has improved accessibility. The place is now suitable and attractive for new dwellers. An increase in property value is observed. The requirement of office on the main road. the rent of the office is too high so we give an alternative to the people who cannot afford an expensive office place. Yes got permission from the authority. No obstruction was faced.

R-18

I have rebuilt my house (redevelopment). No need in the near future. The condition of the building was not good. the building was first built in 1987. The place is attractive for resident and land value has also increased. Yes, permission was granted by the authority. I faced a few hurdles while taking approval of the map.

R-19

No, I have not made any construction or change. I don't have financial resources and at the moment I also don't need any change. No need in the near future.

R-20

I made a storey addition after BRT development. BRT was one of the reason behind this construction as I can earn money by renting the upper portion of my property. Moreover, we also needed additional space. Yes, property value has increased 2-3 times and the place now has better accessibility and connection with the rest of the city. No, I asked first to get approval but it was not approved by the authority. Permission was not granted by the authority.

R-21

I have done redevelopment with the addition of one storey. BRT was one of the reasons behind this construction. Moreover, the condition of the building was not good enough. Yes, property value has increased with better accessibility and more attractive for the resident. The demand for renting has also increased. No obstruction was faced because my son is working in LDA.

R-22

Storey addition is the change done after BRT development. Yes, I would like to make the front facade more beautiful. There was a need for additional space. Yes, property value has increased with better accessibility and more attractive for the resident. The demand for renting has also increased. I faced financial obstructions while construction of the additional storey.

R-23

No, I have not made any change. The building is already 3 storeys and doesn't need additional space.

R-24

I have made a storey addition. In future, I would like the conversion of residential property into residential/commercial (Mix). To earn money by renting additional space as people require a place for living. The place has better accessibility and more attractive for new dwellers. Moreover, property values have also increased. Property value increase for commercial purpose.

R-25

Redevelopment and improvement in the front façade. No not expecting any change in the future. The condition of the building was not good enough. Property price has increased from 1-2 lack. No permission is obtained from the development authority. I did not face any obstruction.

R-26

No, I have not made any transformation. No need for any change moreover, I do not have financial resources. In the future, I would like to divide commercial shop into two parts.

R-27

Redevelopment and storey addition. The condition of the building was not good. Property value has increased as BRT provided better accessibility and the place is attractive for residents. Yes I took permission from the Lahore development authority. No obstruction was faced as already got approval from the concerned department.

R-28

I made Storey addition. I made this change because additional space was required. No, did not get any approval majority of persons in our area don't get approval. There was no check-up from the relative authority during construction. There were some problems for the moment of materials due to narrow streets.

R-29

Have made Land use change from open space to residential. I want to change the land use from residential to commercial with the addition of more number storeys. To save rent money from the previous home. previously I was paying 25,000 rent per month on the previous location. The financial conditions, unaffordable rent in the city, increase the price of the building material and to save money from rent. The process of getting plan approval from LDA is not friendly.

R-30

No have not made any change. No need for any kind of change or development. No, don't have any plan for this in the future.

ANNEX-B
INTERVIEW SCRIPT-INVESTORS

Interview Questions

1. what type of business are you running?
2. What were the reasons to invest in this project? why not others?
3. Why did you choose this specific location for your investment? why not other locations?
4. Did you consider BRT as the main/minor factor while investing? considered BRT as negative or positive?
5. What other factors related to urban development did you consider?
6. Has your business flourished with the passage of time?
7. What are the returns on your investment? are these positive or negative?
8. What kind of difficulties did you face when you were planning to invest in this business?
9. What do you think can government play its part in reducing these difficulties?
10. How do you see investing along BRT compared to other locations in the city? pros and cons?

I-1

Well, I am running a fast-food point (Burger and Shwarma point) and I am doing this business for almost the last 3 to 4 years. Actually, I was already working on the same type of business I got some experience from there and started this business afterward. Yeah, this location suits me the best. I also searched other sites but basically, this is the nearest distance I can travel daily from my house. The majority of people use this BRT station to travel to their house or offices, so they prefer to stop here a while and eat from this place as it's the nearest food point facility available here. Secondly, this is the main link that connects DHA local people with Ferozepur road and its surrounding areas. No, I didn't consider it. As already mentioned this place was a potential food point surrounded by offices which was the major reason for investment. No, actually I am not so clear about urban development factors. Yeah by the time, my business has flourished. I have about 30 to 40 percent more business during evening time (closing of office hours). I am a bit satisfied and have positive returns on my investment. I am earning around 30 to 40 thousand monthly. I was a little worried about the Selection of business type. As you know, in the present scenario it has become very difficult for a middle-class man to start his own business in a high-risk environment.

I-2

It's a book shop. The margin of profit is relatively high in this business as compared to others. 20-25 percent on some items and 30-40 percent on some items. This site is easily accessible for all categories of students. It is located on the main road, there are many schools, colleges, and universities around here. This shop was already here before the BRT corridor then we extended the business after BRT. However, BRT has positive impacts on our business that's why we have made changes and invested more. Yes, this location best suits my business type because there many schools and colleges around here. Yeah by the time, my business has flourished much. With the passage of time, the number of students, schools, and other training institutes has increased around here, which has a very positive effect on my business. I am satisfied, my business has grown very much in the last few years. I think purchasing a shop at the main location is one of the main difficulties nowadays as there is a lot of demand for commercial activities. Moreover, land prices have increased a lot. Yes in my point of view the government should encourage small businessmen by providing them small loans in different payback packages. It is a good and profitable location for investment. Small shops/business opportunities have upsurge along the BRT corridor.

I-3

I am running a shoe shop. Previously I was working as a government servant then I started this shop in 2015. A major part of my investment was from my retirement payment. Actually my son is already having a shoe shop, I used to sit there also, I am quite aware of this business, and so I preferred to continue in the same business type. Yeah, this location suits me the best. It is very near to the main road and hub of commercial activities and easily accessible for all categories of people. This corridor has become the hub of different commercial activities. It is easily accessible for all people. Yeah by the time, my business has flourished much in a positive way. Now profit margin has declined after the formation of the new government before it was around 30-40 percent now it's 20-30 percent. Faced few problems from local authorities. The government should give some relaxation to the new investors in form of tax reduction and provide interest-free loans to encourage more investment in different developmental setups. In my point of view, the growth of any business depends upon different factors including the location of the site, type of business, demand in that specific area, etc.

I-4

PAN shop, I am running it for the last 3 years. This shop is on rent and I am giving 20 thousand rent per month. This is one of the more profitable options as compared to other options and I got financial help from my friend to set up this business. This location is very near to the BRT terminal. The majority of people travel through BRT throughout the day. They prefer to buy cigarettes or Pan from here. Yes one of the major reasons for investing at this site is the BRT corridor. As its last bus station, the bulk of people stop here for their daily travel. Yes new commercial opportunities were considered while making the investment. Yes this place, it's far better than other locations in the city. My business has flourished much. 30 to 40 percent of my investment. It was difficult to find a place near the corridor as property value has increased after BRT. Well I am not sure about it. May be Government can reduce taxes to give some relaxation to small vendors like me. It's a small business and everyday commuters of BRT mostly come here. The location of a Pan shop near BRT station gives you good business.

I-5

I am building an apartment building. There are 80 apartments and 40 shops. The profit percentage is relatively high in this specific type of business. Its location is near to city center, people usually coming from far areas, prefer to live here on rent. My property was already in this place and after BRT development there is potential for new housing and commercial uses. After BRT development value of the property values have also gone up. I have already mentioned that after BRT my property value has increased and people prefer to travel through this bus service. Yes, this place is in the center of Kasur and Lahore city. It's very near to services hospital and Kalma chowk. Now due to the development of BRT property and rent value of this site is also increasing day by day. Yeah by the time, my business has flourished about 30 to 40 percent. But in 2019 due to revised taxation policy profit ratio has become very low. I am satisfied, but overall it has decreased with time due to the financial condition of the country. I was a little worried because the overall project cost increased as compared to the estimated cost in BOQ due to an increase in the prices of material. The government should give relaxation to the construction industry. This will ultimately generate more job opportunities. In my point of view, BRT provides very easy access to all these sites at very low cost, plus location plays a very important role in the development of any kind of business. BRT has generated the demand for new housing as well as new commercial uses by providing better accessibility.

I-6

Its sanitary fixtures and tiles business. Actually this is our family business, we are running it for a long time, so I opted to continue in the same type of business. My shop was here before the construction of BRT and we have extended our business and made more investment. At Ichra station there is a trend of sanitary and tile business and people from wider areas came here to buy sanitary and tiles. No, as I said earlier we are already running this shop before BRT here however we have put more money into this. But after BRT road has been dived in left and right portions due to which our business profit ratio has reduced. Center of Ferozepur road, markets of tiles, and more business opportunities. The is a trend toward commercial development. My business has flourished much with the arrival of BRT. The accessibility benefits provided by BRT have brought more business and customers for us. The returns on investment are about 20 to 25 percent. It was difficult to gather resources for investment. The government can provide loans to new investors on low interest and give relaxations in taxes to beginners. It's a profitable site for investment in some specific type of businesses. However, on every station, there is a different trend for business opportunities. BRT provides better accessibility benefits and attracted customers from all parts of Lahore.

I-7

It's an electric shop and we have shops on multiple locations in Lahore. At this location, this type of business suits me best. We also have other branches at different places but this place is quite near to main electronic market that why best suits for electronic business. Yes, we have a shop on the other side of the road as well. BRT divided the road into left and right which has also restricted the moment of our customers. So, we opened a new shop on the other side of the road as well. The commercial activities have increased after BRT. Yes, our business has flourished. Yes, the government can help by reducing taxes on electronic devices. BRT corridor is a good site for investing in this type of business as it is near the main market and also creates a positive competitive environment. BRT provides better accessibility benefits and generates economic activities by attracting customers from all parts of Lahore.

ANNEX-C
INTERVIEW SCRIPT-REAL ESTATE AGENTS

Interview Questions

1. Is there any change in property value? (commercial/residential)
2. Please describe the pattern of change near the station and in other areas? (in term of before and after property value)
3. How you see land-use change along the corridor (along which section)? Is there any change?
4. What is the reason for not having multi-storey development? and what can be done?
5. Is there any change in traffic condition? Congestion has increased/reduced?
6. Is there any effect of BRT on Business? (Positive/Negative) and on which type of business?
7. How do you see the role of local authorities in urban development? Improving traffic conditions? Economy?

EA-1

Property values have increased along the corridor which is more apparent around BRT station. Near the station area, there is a 100% increase in property values. Residential values have increased from 4 to 8 lac whereas commercial properties have increased from 14 to 20 lac. Land-use conversion is observed near Ichra, and the city center and new development activities are observed around Gajjumata and Yohanabad. If we want to build higher there is a need to stop new development on agricultural areas. The development of BRT has improved traffic conditions and lessen congestion. BRT gives space to the economy for up-gradation.

EA-2

There is an increase in the property values from 5 lac to 8 lac which is more along the main corridor. Most of the people have done commercial development. If we want to build higher we need to give tax relaxation. BRT has resulted in less congestion. There is a lack of development authority for economic and urban development.

EA-3

There is an overall increase in property values. Residential properties values have increased from 4 lac to 8 lac and for commercial properties values have increased from 18 to 35 lac. There is a conversion of land use from vacant to commercial. Moreover, redevelopment activities have also been observed. In order to encourage high-density development government should restrict horizontal development. Congestion has reduced after the development of BRT and accessibility to different places have also improved. There is an upsurge in economic activities due to improved accessibility.

EA-4

Neart the station areas there is an increase from 60-80%. Properties from further away from the BRT station have a gain of 40-60%. Land use transformation has taken place mostly from residential to mix. Ichra station has experienced redevelopment activities. There is a need to stop the development of new housing schemes. Accessibility has improved and congestion has reduced after BRT operation. The improved accessibility has a positive impact on business development. In the future, there would be more high-rise development along the corridor.

EA-5

Property values have increased along the corridor. Residential property value has increased from 8 to 15 lac whereas commercial property values have increased from 25 to 45 lac. New commercial activities are more apparent. Some areas have also observed redevelopment activities. The main problem of high-rise development is that people are not willing to build higher as they want to enjoy unlimited ownership rights which is not possible in the case of high-rise development. The government should take the initiative for high-density development. Traffic condition has improved however BRT has divided the main road which also restricts the moment of the customers. Eventually, there is an impact on sales.

EA-6

There is a more increase in property values as we move closer to BRT. Near BRT station there is an increase of almost 12 lac. The properties away from the BRT station experienced an increase of 4 lac. There are more commercial activities on this corridor. New development and development are mostly been observed along the corridor. People's behavior restricts high-rise development as there is an issue of ownership in high-rise development. With commercial development economic activities have also increased.

EA-7

Residential property values have increased from 5 to 8 lac and for commercial use, this increase is from 30 to 50 lac in commercial areas. Land-use conversion is more evident along the corridor. The government should take initiative to promote high-rise development. Traffic conditions have improved and BRT provided good accessibility to different areas in Lahore. Business in the areas around BRT has flourished.

EA-8

There is an increase in property values. Property values for residential use have increased from 10 to 18 lac. For commercial use, property values have increased from 45 to 65 lac. There is a trend toward commercial development. The area around kalma chowk is already mutli-storey. Traffic condition has improved. With improved accessibility, there is an increase in customers from areas around the BRT corridor.

EA-9

Property values have increased from 6 to 10 lac. Moreover, there is more commercial development after the implementation of BRT. In multi-storey buildings, there is an issue of ownership and the government should make regulations related to this. Generally, congestion has reduced after the development of BRT. There is a positive impact on business activities and improved accessibility has brought additional customers to the area.

EA-10

Residential values have increased from 5 to 10 and for commercial use values have increased from 25 to 55 in areas around shama chowk. Building regulations hinder the development of multi-storey buildings. Moreover, there is also an issue of ownership that restricts building higher. The government can give incentives for high-rise development. There is a positive effect of BRT on economic activities and traffic conditions have improved.

EA-11

Property values have increased around BRT stations. After the development of BRT more commercial activities have been observed. Mostly, building regulations and financial issues refrain people from building higher.

EA-12

A positive trend is observed in the value of commercial use that has increased from 15 to 27 lac. Most people have converted their residential buildings into a mixed development. The government should give tax relaxation for high-rise development. The congestion has reduced after development of BRT. There is an increase in business activities which is apparent through improved accessibility.

The research reported in this dissertation was conducted at the Center for Mobility and Spatial Planning, Department of Civil Engineering, Faculty of Engineering and Architecture of Ghent University and Transportation Research Institute (IMOB), Hasselt University. The research is funded by the Higher Education Commission of Pakistan (HEC-Pakistan).

ISBN
978-94-6355-492-3

Cover design
Roger Van Hecke and
Charlotte Alice Dossche

Interior design and production
André Diepgrond / In Ontwerp, Assen

Digital access
Jan-Kees van Loon, New Ink
Communicatie, Groningen

PhD Series InPlanning

Published by InPlanning
Oude Kijk in 't Jatstraat 6,
9712 EG Groningen, The Netherlands

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