Curtin University Sustainability Policy (CUSP) Institute

Incorporating Equity in Public Transport Planning: The case of Bengaluru

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DECLARATION

To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgment has been made.

This thesis contains no material that has been accepted for the award of any other degree or diploma in any university.

Human Ethics: The research presented and reported in this thesis was conducted in accordance with the National Health and Medical Research Council National Statement on Ethical Conduct in Human Research (2007) – updated March 2014. The proposed research study received human research ethics approval from the Curtin University Human Research Ethics Committee (EC00262), Approval Number # HURGS-04-14.

Signature: 

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ABSTRACT

Public transport (PT) and its associated developments are emerging as sustainable urban transport solutions. However, the rapidly increasing investments on them are not yielding equitable benefits for all. To address these inequity concerns, the study proposes a methodology to evaluate and incorporate equity related aspects into PT planning at the station area and network levels, and demonstrates the methods in Bengaluru, India as a case study. The equity solutions for station area level planning are illustrated in Yeshwanthpur industrial area (in Bengaluru's suburbs) as the primary case study.

At the station area level, the study developed a series of methods to: assess which income groups are being excluded from transit oriented developments (TOD); identify gentrification in TODs; evaluate the probability of replacement, in future, of the poor from TODs; and assess the implication of such social exclusion on PT ridership, through the development of a new model. In addition to incorporating equity into TOD planning, the study developed a framework for stakeholder deliberation towards developing affordable housing strategies for more inclusive and sustainable TODs.

At the network level, the study developed a tool called 'Transit Accessibility and Affordability Index' (TAAI). In contrast to the existing PT performance measures, which evaluate only accessibility, TAAI evaluates both accessibility and affordability of PT. It was administered to Bengaluru using the software TransCAD, yielding recommendations for incorporating equity at the network level.

Demonstration of the proposed research methods at the station area level indicates that the new TODs are 68% costlier than the houses located in suburbs, and are excluding the income groups with annual income below INR 0.6 million, thus causing new build gentrification. The detailed case study analysis conducted in Yeshwanthpur industrial area illustrates that while the new developments are causing gentrification, the old build existing housing remains ungentrified. It also demonstrates that in a 'do nothing scenario' it is highly probable that the availability of vacant and brownfield land could contribute to further social exclusion. An assessment of the impact of such social exclusion on PT ridership indicates that though the gentrifiers account for a small part of the bus ridership, they are significant contributors to the metro's ridership due to its high level of service.

However, the probability of the non-gentrifiers using metro is higher than that of the gentrifiers. Hence, the study recommends incorporating affordable housing in new TODs, to not only ensure equity but also further optimise the metro ridership. In this regard, a stakeholder deliberation was conducted and potentially feasible strategies were identified. These strategies are: inclusionary zoning, special purpose planning vehicles, land banking entities, innovative financing tools, and local area level plans.

The administration of the TAAI tool at the network level in the case study area shows that the PT generalised cost (GC), a composite measure of accessibility (travel time) and affordability (travel cost), decreased by 15% following the high-speed metro's introduction. However, PT GC is higher than that of the motorbike and the car. This is attributable to PT's higher access, egress and waiting times (out-of-vehicle time); lower average trip length; high PT fares; and the minimal operating costs of private vehicles. In light of this cost difference, the study recommends mode integrated strategies towards a PT system more competitive with motorbikes, in Bengaluru.

The framework and tools to evaluate and include equity related aspects in PT planning, developed in the study, are applicable to cities across the globe. The study creates awareness among policy makers, planners and city authorities, on equity implications in PT planning and management.

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DEDICATION

I would like to dedicate this thesis to my husband Kesava Naidu, son Sathvik and parents Sheshagiri Rao, Durga and sister Nagamalleswari. Their patience, support and understanding throughout this doctoral research has made this all possible.

MANUSCRIPTS SUBMITTED AS PART OF THIS THESIS

Statement of Contribution of Others

All of the manuscripts submitted as part of this PhD were drafted, designed and coordinated by Jyothi Chava. The majority of the calculation and writing for each publication was undertaken by Jyothi Chava.

Signed detailed statements from each co-author relating to each manuscript are provided in the manuscripts section.

MANUSCRIPTS SUBMITTED AS PART OF THIS THESIS

Manuscript 1: Chava J., Newman, P., and Tiwari R. (2016). Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore. Submitted the first version to *Urban Research and Practice* on 20th March 2016. The revised version after review was submitted on 29th May 2016. Manuscript ID: RURP-2016-0009.

Manuscript 2: Chava J., Newman, P., and Tiwari R. (2016) Gentrification of station areas and its impact on transit ridership. Submitted to *Case Studies of Transport Policy* on 10th April 2016 and sent to reviewers. Manuscript ID: CSTP-D-16-00048.

Journal paper 3: Chava J and Newman P (2016) Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit Oriented Developments. Sustainability, 8(10).

Manuscript 4: Chava J., Newman, P., and Tiwari R. (2016) Transit Accessibility and Affordability Index: A tool to evaluate transit quality. Submitted to *Transportation Research Part A* on 29th June 2016 and sent to reviewers. Manuscript ID: TRA_2016_532.

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1 Introduction

Public transport (PT) equity refers to the equal distribution of PT access benefits (Litman and Brenman, 2012; Litman, 2013). Due to urban sprawl, disruptive traffic, and hazardous non-motorised transport (NMT) infrastructure, improved access to PT has become a prerequisite for all income groups to be able to participate in any city's economic, social and cultural activities (Cervero, 2011; *National Urban Transport Policy*, 2001; Pucher and Renne, 2003). To meet these income groups' accessibility needs—especially of those without access to private vehicles—PT planning must be equitable.

PT planning involves micro and macro levels. PT planning at the micro level refers to planning around station areas or what is called transit oriented development (TOD) planning. The macro level includes PT network planning at the city level. Traditionally, cities viewed the investment on PT as a mobility improvement measure aimed at easing travel between two points, and focused primarily on network level planning (Manaugh, 2013; Suzuki et al., 2013). Recently, cities like Hong Kong, Singapore and Copenhagen have demonstrated how PT can serve as a tool to improve not only mobility but also accessibility, by integrating land use and PT through TODs (Cervero, 2010; Cervero and Murakami, 2009; Suzuki et al., 2013). TODs are compact, involve mixed land use, and are NMT friendly, mostly located around 400 to 800 m of a centrally located PT station (Cervero and Kockelman, 1997; Guerra et al., 2011). PT and TODs help reduce the need to travel, improve PT and NMT ridership, and reduce private vehicle usage (Cervero and Kockelman, 1997).

Due to the benefits mentioned above, PT and its TODs are emerging as sustainable urban transport solutions and the investments on them are gaining momentum across the globe (Litman, 2005; Newman and Kenworthy, 1999; Newman and Kenworthy, 2015). Cities are providing various planning incentives for TODs, to channelize urban growth around a

well-planned PT system and to encourage sustainable transport mode shares (Chatman, 2013). However, while planning PT systems and their TODs, cities focus on economic and environmental objectives and pay less attention to social repercussions. As a result, how the PT system and its TODs serve various income groups (to achieve PT access equity) has not gained much attention in TOD planning (Litman and Brenman, 2012).

At the station area level, planning incentives combined with high-quality PT accessibility are attracting higher capital investments (Loukaitou-Sideris, 2010) and increasing land and rental values (Knaap et al., 2001; McIntosh et al., 2013; Newman and Kenworthy, 2015; Renne, 2014; Topalovic et al., 2012; Yan et al., 2012). The higher housing cost of new developments and the increase in rental values of old ones can render the coveted TOD areas unaffordable for the poor, who will therefore remain excluded from the new developments and be replaced by the affluent in the older ones (Chapple, 2014; Chapple, 2009; Kahn, 2007; Lin, 2002) . This process of social exclusion in TODs is termed 'gentrification' and has been traditionally considered an equity issue of TODs (Chapple, 2014; Pollack et al., 2010). The inequity in TODs can impact the PT ridership, thus defeating the purpose of the TODs (Pucher and Renne, 2003). Some cities in developed countries are adopting various strategies to combat gentrification issues in TODs (Center for Transit-Oriented Development, 2009; Litman, 2013a; Shoemaker, 2006).

The coexistence of the rich and poor in developing countries is often seen to create neighbourhoods that are mixed income in nature, and thus it can render the spatial disparities in income less obvious than in developed countries (Walker, 2013). Therefore, in developing countries, as the cities begin to build new metro systems (as is occurring in India and China,), it is possible that the social exclusion process and the resulting gentrification in their new TODs could remain inconspicuous. On the other hand, the process may follow the developed world and create greater inequity through the new transit and TOD process. Unfortunately, the existing literature does not focus on gentrification issues in TODs in the developing world. There is also therefore little written on strategies to mitigate inequity in the developing world's context if TODs and gentrification were emerging. The PhD research project attempts to fill the literature gap by evaluating such a city (Bengaluru) where inequity in TODs could be emerging, to

examine the implications for PT ridership, and to identify potential strategies at the micro local land use level to mitigate TOD inequities.

At the network level, according to Cervero (2011), PT inequities can be attributed to the PT systems' inaccessibility and unaffordability for urban residents. The existing literature demonstrates that the PT planning and evaluation measures focused only on PT accessibility and neglected the affordability aspect. PT may be accessible to the poor but not affordable if the fares are high, especially in developing countries like India (Arora and Tiwari, 2007; Tiwari, 2011) and an affordable PT system may not necessarily be accessible, if the travel times are high (Muley, 2011). To achieve PT equity, cities need to ensure accessible and affordable PT for all the residents (Cervero, 2011). To facilitate this, firstly, the planners must evaluate the PT accessibility and affordability to identify the service gaps in the existing transport system. Subsequently, they must assess the impact of various new PT proposals on improving PT service quality, to select the best PT plans for the future. However, as highlighted above, the existing assessment measures do not focus on affordability aspects. Hence, the PhD study proposes a new composite PT performance measure to evaluate the PT accessibility and affordability across the city.

The study views Bengaluru, India as a case study to demonstrate how to incorporate equity in PT planning at the station area and network levels. Bengaluru was preferred for the case study considering its metro system became operational recently and is undergoing expansion (Bangalore Metropolitan Rail Corporation Limited, 2016), and its new PT systems such as bus rapid transit and commuter rail are still in the pipeline (RITES, 2012). Additionally, the city authorities have been encouraging high densities in TODs—to increase the PT ridership—by offering a high floor area ratio (FAR) as a planning incentive (Government of Karnataka, 2009). The higher FAR policy and the improved PT accessibility are likely to have triggered new dense high rise TOD projects in station areas and thus these areas may be demonstrating inequity that can be measured and analysed. This study can thus provide the stakeholders with insights into the implications of the new PT system—and its associated developments—on equity objectives, and can provide an opportunity to guide policy actors on incorporating equity in future PT system plans.

The framework and tools—developed in the research project—to evaluate and include equity aspects in PT planning are applicable to cities across the globe, especially in the developing world where new transit and TOD is being undertaken extensively. The thesis thus sets out to create awareness among policy makers, planners, and city authorities, on PT equity aspects. The PhD research aims, objectives and thesis structure are presented below.

1.1 Research Aims

The overarching question this research seeks to answer is:

'How can equity objectives be incorporated in transit oriented development planning and public transport network planning, to achieve a more equitable public transport system particularly in the developing world?'

To address the above question, the research primarily aims at:

1. quantifying the equity aspects of TODs (in literature and the Bengaluru case study),
2. quantifying the impact of TOD inequities on PT ridership (in literature and the Bengaluru case study),
3. developing a framework to enable equity in TODs through stakeholder deliberation (in the Bengaluru case study),
4. developing a tool to quantify the equity aspects of the PT network based on upgrading previous tools to include both affordability and accessibility, and
5. administering the new tool in the Bengaluru case study area and providing recommendations for equitable PT at the network level, to demonstrate the value of the tool.

1.2 Research Objectives

The first three aims listed above focus on ensuring equity in station area level planning and the subsequent two, in network level planning. The study attempts to achieve these aims through the following objectives that are applied to the Bengaluru case study:

Station Area Level

1. Evaluate the housing equity in new TODs, its association with gentrification, and susceptibility to future gentrification, to assess the probability of replacement and exclusion of various income groups from TODs;
2. Evaluate the impact of TOD gentrification on PT ridership;
3. Develop strategies towards socially inclusive TODs, through stakeholder deliberation;

Network Level

4. Develop a tool to evaluate the accessibility and affordability of the existing and proposed PT system networks, to understand how well these serve the city residents; and
5. Apply the tool to the case study area to: evaluate the existing PT system equity in terms of accessibility and affordability for all urban area residents, evaluate the impact of the metro system on improving equity, and come up with recommendations to improve PT equity for all.

To achieve these research aims and objectives, the research developed four manuscripts for publication. The interaction among the research aims, objectives and manuscripts are shown in Figure 1. The detailed research structure adopted in the thesis is highlighted in the next section.

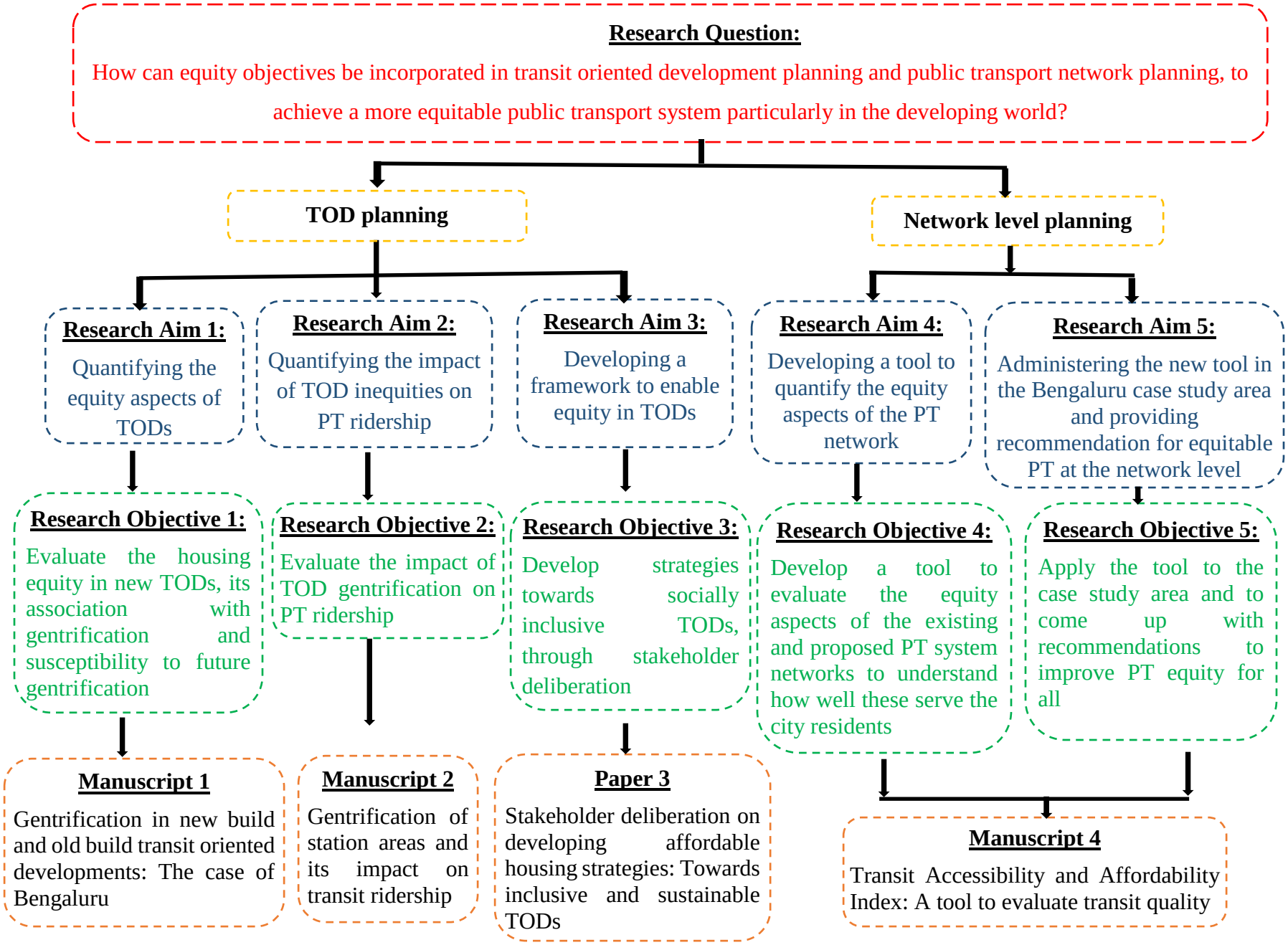

Figure 1: The relationship between research question, study area levels, aims, objectives and manuscript

1.3 Research Structure

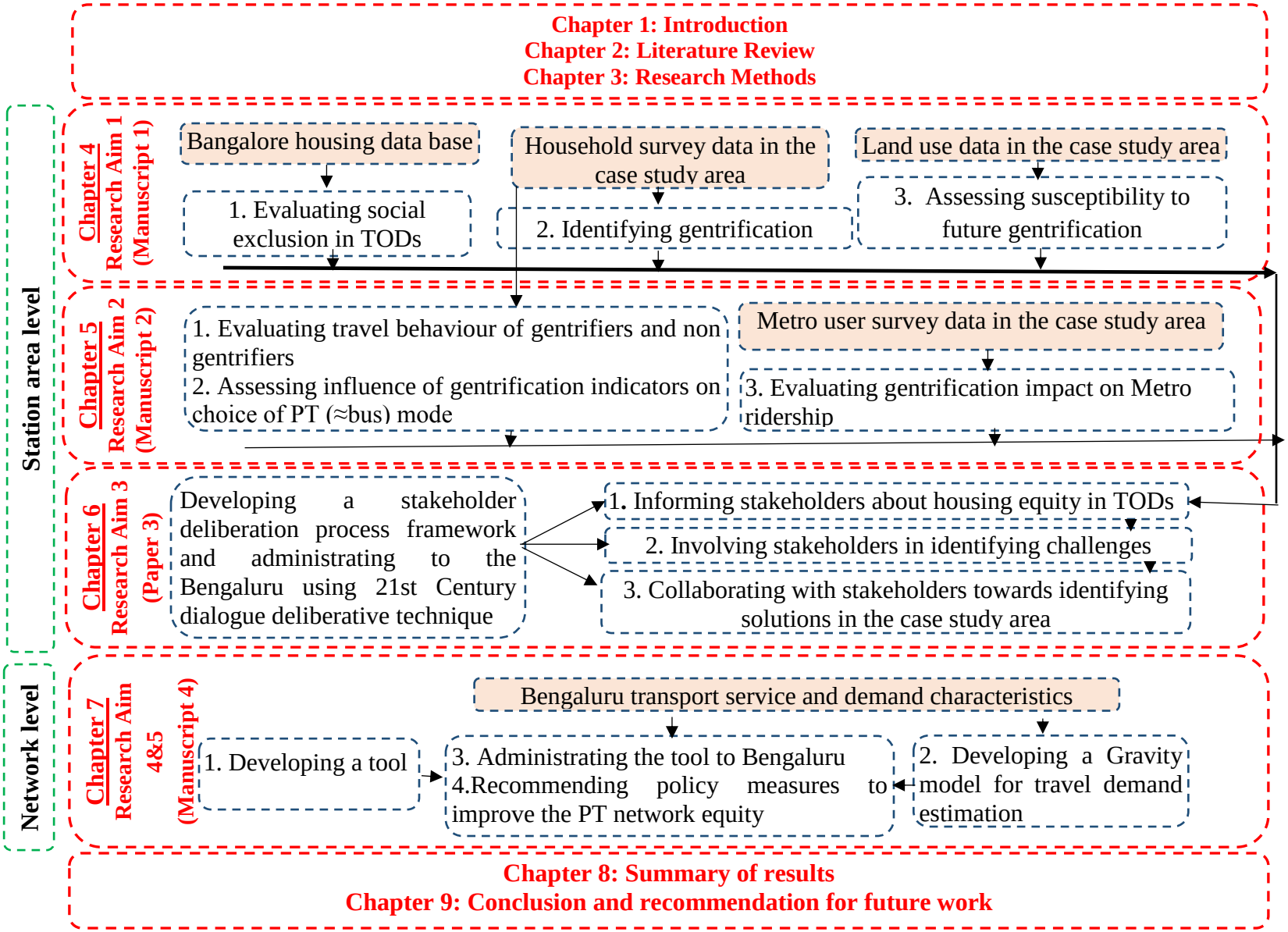

Figure 2: Schematic diagram illustrating the hybrid thesis research structure, and development of each manuscript

Figure 2 presents the structure of the thesis and illustrates the linkages between the research aims, manuscripts, scale of analysis, data sets used, and broad research methods adopted. The research structure was developed around four academic manuscripts that interact with the research aims and objectives to address the research question. The outcomes of each paper were consecutive in nature and were used to incorporate equity objectives in PT planning at the station area and network levels.

The thesis begins with the exegesis that includes a brief introduction, summary of literature review, brief description of research methods adopted, overview of the four manuscripts, results, conclusions that incorporate equity in PT planning, recommendations for future work and the manuscripts in full along with the contribution of each author. The appendix includes survey instruments used in the thesis, secondary data, and analysis results.

The first three manuscripts focus on incorporating equity in TOD planning. The quantitative analysis in *manuscript 1* begins with the Bengaluru scale, assessing the income groups that are being excluded from TODs. Subsequently, the analysis progresses to the case study area (Yeshwanthpur industrial area), assessing the equity aspects of new TODs, their association with gentrification, and susceptibility to social exclusion in future. *Manuscript 2* continues from *manuscript 1* and focuses on the impact of TOD gentrification on PT ridership in the same case study area. The results from *manuscript 1* and *2* provide stakeholders with information on the implications of new TODs on equity and PT ridership, and enable effective stakeholder dialogue to identify strategies for inclusive and equitable TOD planning, which is the focus of *Journal paper 3*. *Journal paper 3* concludes the discussion on station area level planning. It provides the framework to develop innovative affordable housing strategies—for more equitable TOD planning—in collaboration with the stakeholders.

Manuscript 4 focuses on evaluating and incorporating equity in PT network planning. To evaluate the PT network equity, the study developed a tool called Transit Accessibility and Affordability Index (TAAI). TAAI can be evaluated through any macro-level planning software. The tool has been applied to Bengaluru, India—using the software TransCAD—to assess the existing bus transport equity (in terms of accessibility and

affordability) compared with that of the alternative travel modes, and to assess the impact of the high-speed metro on improving PT equity. Based on the case study area findings, *manuscript 4* offers recommendations for further improvement in PT equity at the network level.

All the manuscripts maintain a focus on incorporating equity in PT planning at the two levels of macro network planning and micro land use planning. The thesis provides a framework to empirically quantify the implications of new TODs on equity and the impact of TOD inequities on PT ridership. It also provides a framework to address the inequity issues in TODs through stakeholder deliberation, which is a concept in its early stages in India. The deliberation framework facilitates stakeholders' dialogue to identify challenges for equitable TODs. Further, it enables the stakeholders to come up with the kind of innovative strategies required—to be embedded into the current policies and regulations—to mitigate the identified challenges in developing more equitable TODs. In addition to this, in contrast to the existing performance evaluation measures, which evaluate only the accessibility of the PT network, the study provides a framework to evaluate the affordability as well, and provides recommendations to achieve equity at network level.

The major contributions of the research, along with the research findings providing guidance for incorporating equity in PT planning and management at both station area and network levels, are outlined in more detail below.

2 Literature Review

This section summarises the literature review conducted as a part of the thesis. The detailed literature reviews—on each subtopic in this section—are included in the full-length manuscripts.

At station area level planning, gentrification is traditionally considered an equity issue. The literature review covers: the studies on gentrification and its evolution; the studies looking specifically into gentrification issues in TODs; the studies on the impact of TOD gentrification on PT ridership; and the studies on the strategies adopted in developed countries to mitigate gentrification in TODs.

At the network level, the lack of an accessible and affordable PT system is attributed to PT inequities. The literature review looks into the existing PT performance measures and tools adopted by planners while planning future transportation systems.

2.1 Gentrification and its Evolution

Defining gentrification is a complex process as its definition is constantly evolving (Song and Zhu, 2011). Gentrification was traditionally defined as a process of displacement of the working class by the middle class in the central city areas of industrial cities as they de-industrialised (Glass, 1964; Smith, 1982).

The evolutionary process of gentrification, since the mid-20th century, is classified into four phases/waves. The classification is depending on the actors, type of the space and the gentrification consequences. The first two waves of gentrification lead to the direct displacement of the poor from the central city area, and can be termed 'classic gentrification'. These two waves are different in that the first entails sporadic and isolated gentrification and the second, anchored gentrification (Van Gent, 2013). Such classic gentrification is apparent in developed countries' cities, whose inner city areas witnessed huge reinvestments in the late 20th century (Atkinson, 2000; Bourne, 1993; Freeman and Braconi, 2004; Tsietsi Monare et al., 2014).

In the mid-1990s, large scale capital investments triggered a new (third) wave of gentrification (Smith, 1996). This wave travelled globally, reaching developing countries

like India (Hackworth and Smith, 2001; Murphy, 2008; Rérat et al., 2010; Van Gent, 2013; Visser and Kotze, 2008). This wave saw gentrification move outside the inner city areas. This contemporary gentrification is diversified and can take various forms: the classic form (direct displacement); new build gentrification (new developments on brownfield/vacant land for the middle class, excluding the poor); super gentrification (a subsequent wave, replacing the middle class with an elite group); and managed gentrification (where the state maintains a balance among income groups) (Davidson, 2007; Davidson and Lees, 2005; Land et al., 2012; Rérat, Söderström and Piguet, 2010). The last (fourth) wave originated in USA following the brief economic crisis in 2001. It was triggered by the financial transformation of housing combined with the consolidation of pro-gentrification policies and polarised urban policies (Van Gent, 2013).

The study views the different forms of gentrification as ‘old build’ or ‘new build’, the former signifying the displacement of the poor from their traditional TOD housing, and the latter signifying the exclusion of the poor from the new TOD housing (housing initiated after high density policy).

Different countries, cities and neighbourhoods may experience different phases of gentrification, varying in form and time frame depending upon their socio-economic system and cultural background. Table 1 illustrates gentrification and its evolution in various countries.

Table 1: Gentrification and its evolution in various countries

Study	Country	Gentrifications phase	Players	Form
Tsietsi Monare et al., (2014) Visser and Kotze, (2008)	South Africa	First phase from 1950-1980	Middle class residents reinvestments at local level	Classic
		Second phase from mid 1990s	Urban renaissance in the former CBD areas by private investors	Classic
Lees et al., (2008); Newman and Wyly, (2006); Wyly and Hammel, (1999)	America	First wave until the early 1970s	House owners, developers and pioneer gentrifies investments in the disinvested inner city housing	Classic
		Second wave from 1978-88	Developers and urban investors who made neighbourhoods as a real estate frontiers	Classic
		Third wave from mid 1990s	State reforms (privatization, decentralization and housing reforms) to support mixed income neighbourhoods associated with large scale capital investments	Managed and state led
		Fourth wave since 2001	Financial transformation of housing market (low interest rate, increased consumer borrowing and spending) due to global financial system.	New build and super gentrification
Van Gent, (2013)	Amsterdam	First wave in mid 1970s	Low interest rates, investments by young population in the city center.	Classic
		Second wave from 1985- 1989	Investments in the historic city center by private investors, developers.	Classic
		Third wave from 1990- 2008	Housing memorandum introduced in 1989 to: push privatization of housing; decentralise the responsibility of social housing (from national to local level); and promote ownership.	New build gentrification
Rérat et al., (2010)	Swiss Cities	First wave and second wave	NA (low housing cost in urban areas; Swiss tax system – which encourages owners to regularly renovate their	No evidence of classic

Study	Country	Gentrifications phase	Players	Form
			buildings; regulations which makes it very problematic for property owners to cancel leases).	
		Third wave	High end apartments by corporate real estate developers in the central city areas.	New build gentrification
He, (2010) (2012) Song and Zhu, (2011)	China	First wave	Private investments on luxurious high raised structures and infrastructure betterment projects at sporadic locations in city center	Classic and new build
		Second wave	Ambitious large scale urban redevelopment projects to cater to the rich in old urban areas anchored by municipalities	Classic and new build

Most of the countries and cities highlighted in Table 1 belong to the developed world, where the inner city areas were neglected after World War II and social segregation between the rich and the poor had prevailed traditionally. In contrast, the developing countries display mixed income habitation and the inner city areas were not neglected. It is thus of interest to see if the newly developed TOD housing in developing countries is creating equitable and socially inclusive neighbourhoods or causing gentrification (like in developed countries). To check for any form of gentrification in Indian TODs, it is worth reviewing the research methods—to identify gentrification in TODs—adopted by other countries. The following section summarises this approach.

2.2 Gentrification in TODs

Moving on from the brief introduction to the gentrification process, this section summarises the research studies that focus on gentrification specifically in the context of TODs. These studies guide how to identify and evaluate equity aspects in TODs. Unfortunately, in India, the literature on this issue is limited, as gentrification and TODs are still in early phases in most developing countries. Nevertheless, studies on some cities in developed countries can provide suitable indicators needed to help quantify any possible TOD inequities in India. These studies are summarised below.

Table 2: Studies on Gentrification in TODs

Study	Country/ City	Indicators to identify gentrification	Comparison	Results
Lin, (2002)	Northwest Chicago	Residential property value.	Census tracts (CTs) within half mile radius of PT station vs. CTs away from PT station.	Properties adjacent to PT station has 20% higher increase in value than the houses located half mile away.
Kahn, (2007)	14 cities in the Unites States	Average home, prices, share of college graduates, and length of time for which CTs were exposed to PT.	CTs within one mile of park and ride station vs. CTs within one mile of walk and ride station vs. CTs away from PT stations.	Greater gentrification in walk and ride stations than the park and ride stations.
Feinstein and Allen, (2008)	Boston	In migration rate, education, household (HH) income, HHs receiving public assistance, average rent and percentage of owner occupied homes.	CTs within 1.4 mile form PT station vs. all the CTs within the Boston Metropolitan Statistical Area (MSA).	The CTs next to PT are compelling less affluent, long established residents in rental housing to move.
Pollack et al., (2010)	12 MSAs, in the USA	Population growth, housing supply, racial and ethnic composition, HH income, housing cost, in-migration rate, PT mode share and motorised vehicle ownership	42 neighbourhoods located within 1.5 mile of PT station in 12 metropolitan areas are compared with their respective MSA average.	The study found evidence of gentrification in the majority of newly PT served neighbourhoods
Grube-cavers and Patterso, (2015)	Montreal, Toronto and Vancouver	Average income, degrees per capita, average monthly rent, occupations and percentage of owner-occupied dwellings	Study adopted statistical modelling taking distance from centroid of CT to PT as independent variable.	The study concluded that the distance from rail has a significant impact on gentrification
Chapple, (2009)	Bay area, CA	Housing price, education attainment.	Low-income neighbourhood in a central location vs. Bay Area region as a whole	The study found that, gentrifying neighbourhoods are nearly twice as likely to be located within one-half mile of transit than any other kind of neighbourhood

All the aforementioned studies focused on change in TOD socioeconomic characteristics over a period of time and compared it across neighbourhoods/cities. They identified the neighbourhoods with significant change, as going through gentrification. For many TOD neighbourhoods, the change is significant. Based on these findings, research often takes this change to be resulting from classic gentrification. However, none of these studies has documented how the neighbourhood's socioeconomic characteristics improved compared to the rest of the city, the process that drove the improvement (influx of gentrifiers/influx of new residential developments/improved status of existing residents) and what the consequences were (direct or exclusionary displacement, or no displacement). Moreover, the results from existing studies may not be directly applicable to cities in India or other developing countries. In such cities, large socio-economic disparities exist, but spatial disparities in income are less obvious because of the coexistence of the rich and the poor due to a combination of cultural and economic factors (Walker, 2013). Hence, it is not clear if PT and associated new TODs have a gentrification effect on Indian station areas, like in some cities in developed countries. If a gentrification effect is triggered, what is its form and what are the consequences? M*anuscript 1* addresses this query in the context of Bengaluru, India by adopting the gentrification indicators from the above studies.

To identify the inequities in TODs, *manuscript 1* adopts most of the gentrification indicators incorporated in the above studies, except three that are not applicable in this context. These three are: from Kahn's (2007) study, the length of time for which census tract (CT) were exposed to PT; from Feinstein and Allen's study (2008) and Pollack et al., (2010), the in migration rate; and from Pollack et al., (2010), racial and ethnic composition. The first two indicators are meant for macro/city level analysis and are applicable only when comparing a neighbourhood with others. They will not be applicable for single neighbourhood analysis (micro level analysis). The third indicator is not applicable to the Indian context or perhaps any other place than USA. In addition to these indicators, the study incorporated housing affordability index (ration of housing price to income), rent burden (rent/income), length of the stay, age of the building and size of the house. The first two indicators help understand the spending patterns on housing. The third indicator provides data on when the residents moved to the study area relative to the transit investment. The last two indicators provide data on the condition of housing.

The gentrification indicators included in *manuscript 1* to identify TOD inequities are: percentage of families receiving government assistance, household (HH) income, average rents, average property price, percentage of owner occupied houses, vehicle ownership rate, education and qualification. The data on these parameters are collected through detailed HH survey in the old and new build developments in the case study area.

To further understand the impact of TOD inequities on PT ridership, the next section of the study summarises the existing literature on the impact of gentrification on travel behaviour.

2.3 Gentrification and Travel Behaviour

The primary objective of encouraging high density TODs through planning incentives is to increase the PT ridership. A few studies in developed countries establish the contribution of the new clustered high-rise TODs towards increasing PT ridership (Arrington and Cervero, 2008; Cervero, 1993; 1994; 2007; Hendricks et al., 2005; Lund et al., 2004; Lund, 2006; Mckibbin, 2011; Muley, 2011). However, there is no evidence to show the impact of the gentrified new high-rise developments on PT ridership.

Four studies (Danyluk and Ley, 2007; Dominie, 2012; Kushto and Schofer, 2008; Pollack et al., 2010) focus on the influence of gentrification on travel behaviour in developed countries. Their results may not be applicable to the Indian context owing to differences in built environment and large social, economic and behavioural disparities, which play a significant role in travel behaviour. Additionally, none of these studies examines the influence of a well-designed PT system such as metro on the travel patterns of gentrifiers. This section provides a summary of the research methods and results of these four studies. They can guide us how to evaluate the influence of TOD inequities on PT ridership in the Indian context.

Table 3: Gentrification and its impact on PT ridership

Study	City	Research method	Results
Danyluk and Ley, (2007)	Toronto, Montreal and Vancouver	Based on occupation and education, gentrification index was allotted to each CT. The index was correlated with the respective CT work-trip mode shares.	The results shows that, the residents of the gentrified CTs are less likely to use PT than the residents of non-gentrified CTs.
Kushto and Schofer, (2008)	Chicago	Income, percentage of renter-occupied houses and education were used as proxies to identify gentrified CTs. The work trip mode shares of these CTs were compared with the non-gentrified CTs.	The study results shows that, PT usage (for work trips) in gentrified CTs is higher than that in non-gentrified CTs.
Pollack et al., (2010)	41 MSAs, in the USA	The mode shares of gentrifying TODs were compared with the respective MSA.	The study illustrates that, PT ridership increases at a slower rate (or, in some cases, declines at a faster rate) in TODs than the respective MSA.
Dominie, (2012)	Los Angeles, USA	Based on income, occupation, education and ethnic composition, gentrification index was allotted to each CT. The index was correlated with the respective CT mode shares.	The study showcase that, PT usage is negatively associated with gentrification.

The literature review indicates that the four aforementioned studies exhibit mixed results, with two showing a positive correlation between gentrification and sustainable transport mode shares, and two showing a negative correlation. All four focus on the city level, use the aggregate data at CT level, regard change in various socio-economic indicators as proxy to neighbourhood gentrification, and establish the impact of gentrified neighbourhoods on transport mode shares.

While analysing neighbourhood level data, parameters other than socio-economic indicators need to be controlled. These include built environment, PT service connectivity, and land-use characteristics, which have a significant influence on travel behaviour (Arrington and Cervero, 2008; Mckibbin, 2011; Pucher and Renne, 2003). Unfortunately, these studies do not include these parameters. Additionally, none of them explores micro level details to understand the contribution of gentrifiers towards PT ridership and the

impact of a well-planned and competent PT system on changing travel patterns of gentrifiers. To remedy this gap, *manuscript 2* attempts to evaluate the implication of the influx of wealthy residents on PT ridership at the micro level, using data from HH survey and metro-user survey. The results can illustrate the implications of TOD inequities on PT ridership, which is the primary objective of PT and TODs.

The next section summarises the strategies and tools adopted by developed countries to address the inequities in TODs.

2.4 Review of Existing Strategies and Tools for More Equitable TODs:

TODs offers its residents a good PT accessibility. To ensure socially equitable TODs, cities need to provide the same access benefits for others with less means. Hence, for more equitable and sustainable TODs, there is a need to accommodate all income groups within the TODs through the provision of affordable housing. To enable this, cities in developed countries are adopting a combination of strategies and innovative tools based on the opportunities, challenges and legislation governing their TOD neighbourhoods (Levy et al., 2006; Quigley, 2010).

Incorporating affordable housing in TODs through implementation of these strategies enables reduction of both the housing and transportation cost and can contribute to further increase in PT ridership (Kniech and Pollack, 2010). In this section few such strategies and tools adopted by cities in the developed countries are summarized. The detailed description of these strategies and tools along with the examples are emphasized in *Journal paper 3*. Shoemaker has broadly classified these tools under three categories (2006):

1. Tools related to zoning regulations, local codes, fees, and procedures,
2. Financing tools, and
3. Joint development program tools.

2.4.1 Tools related to zoning regulations, local codes, fees, and procedures

The tools under this category require a change in regulations, local codes and approval procedures to incorporate affordable housing in TODs. Under this category the existing literature provide predominantly two tools:

a. Inclusionary zoning ordinance: The ordinance works essentially as a trade-off between government and developer (Brown, 2001). It mandates that the developers must set aside a certain percentage of units in the new residential developments as affordable, in exchange for government incentives such as density bonus, impact fee waiver, streamline permitting and relaxing regulations (Benson, 2010; Calavita et al., 1997; Katz and Sawyer, 2003; Weinberger et al., 2010). In exceptional cases, developers may provide land, money, or affordable housing at off-site locations.

b. Accessory dwelling unit (ADU): An ADU is a small unit added to an existing home either through a basement conversion, or in the backyard or above a garage—or included in a newly constructed home. ADUs, typically are small enough to be affordable to the urban poor (Nelson, 2003; Wegmann and Chapple, 2014).

2.4.2 Financing

The tools related to innovative financing methods that can help to fund affordable housing production in TODs are generally one of the following three:

a. Tax increment financing (TIF): TIF funds are generated by the increase in the property and/or sales taxes within a specific district. The additional tax money can be generated by both new development and the enhanced assessed value of existing properties as a result of improvements around them (Shoemaker, 2006). To utilize TIF for the provision of affordable housing, cities has to set aside a certain percentage of TIF funds for the development of affordable housing (The city of Atlanta, 2005).

b. TOD targeted housing funds: Under this ordinance, affordable housing programs funded by national, state and local governments must provide additional incentives for PT proximity (Belzer et al., 2006).

c. Land banking: A land bank is a governmental entity created explicitly to acquire, hold and facilitate developments on vacant, abandoned brownfield properties (Belzer et al., 2006). Land ownership gives more negotiation power to the government entities on type of developments in TODs and enables them to demand for more affordable housing in TODs.

2.4.3 Starting joint development programs in TODs

Joint development programs enable developments in coordination with government, community, and private developers. The tools that facilitate joint development programs to incorporate affordable housing in TODs are generally one of four:

a. Public private partnership (PPP): PPP facilitates the sharing of resources to produce a public vision in agreement. Sharing resources can be land, financing, knowledge, or another valuable component of the development process (Cervero and Murakami, 2009).

b. Joint developments: Joint development allows property interests held by the PT agency to be shared with private entities or other government entities (Mixed-Income Transit-Oriented Development, 2016).

c. Development agreements: Development agreements are contracts between local governments and developers that provide assurances covering long-term planning approvals for a project for a certain number of years (even if zoning policies change at a later date), in exchange for specific public benefits from the developer. Affordable housing can be one of these benefits (Mixed-Income Transit-Oriented Development, 2016).

d. Community benefit agreements: A CBA is a contract negotiated between community groups and a prospective developer, in which the developer agrees to provide particular community benefits related to the project in exchange for the community's support. This tool works well only if community support plays a vital role in the success of a new project's implementation (Feinstein and Allen, 2008).

Overall, the aforementioned literature providing various tools for how to create inclusive TODs. However, each TOD has unique characteristics, the strategies and tools applicable to one TOD may not be relevant to another (Reconnecting America, 2013; 2014). The variation in TOD types are probably greater in developing countries than the developed ones, due to vast socio-economic, land use, real estate market and legislation disparities as well as cultural variations. Identifying the tools either existing or a new set of tools that are applicable to the local context, in collaboration with the stakeholders, improves the odds of implementation of those strategies. In addition, stakeholders can help determine the special local conditions and opportunities that are available in their TOD areas. Hence,

the literature is reviewed in order to propose a *stakeholder deliberation framework* – this framework can then be used to identify affordable housing strategies in a deliberative process that focuses on TOD equity issues. This is provided in *Journal paper 3*.

In the next section, the literature review moves to the network level to ensure equity is analysed in the provision of both an accessible and affordable PT system for all urban residents. Unfortunately, the existing performance measures or tools focus only on PT accessibility. The summary of the parameters they adopted while evaluating PT performance are described below. The detailed description of the research methods adopted by these studies to evaluate PT quality are provided in *manuscript 4* literature section.

2.5 Review of PT Performance Evaluation Measures

Quantifying a PT system's ease of access and affordability is a complex process, given the wide range of interrelated components involved. The four primary components used in this research are spatial, temporal and network availability; and PT fares. Spatial availability assesses the physical proximity of a PT stop from the trip origin (O)/destination (D); temporal availability estimates the opportunity for PT use based on attributes such as headway and operation hours; network availability measures PT route suitability to transport a patron from trip's O to D; and PT fares calculates the money spent to travel along O&D pairs.

The existing PT performance assessment studies exhibit an evolutionary trend. Some are limited to assessing spatial availability, by estimating the population within walkable distance of a PT stop/route. A few also consider temporal availability along with the spatial aspects, considering service within walkable distance may not be taken as 'available' if the PT wait-time exceeds the potential rider's tolerable wait-time. Some studies amalgamate spatial, temporal and network availability into a composite measure. A few also weigh these supply side accessibility characteristics with demand distribution. The demand distribution includes local demand, temporal demand and network level demand. Local demand reflects the population within the walkable distance of a PT stop; temporal demand reflects change in fluctuation in travel demand (local or at network

level) during a day; and network level demand reflects the travel demand between an O&D pair.

However, none of the aforementioned studies considers the PT cost component. For a detailed understanding, the studies on PT performance measures, the components they assessed, and the demand distribution they considered to weigh the service side characteristics, are summarised in chronological order in Table 4.

Table 4: PT performance measure and components they are assessed

Study	Composite Measure	Local availability		Network availability	Local Demand	Temporal Demand	Network Level Demand	PT fare
		Spatial Availability	Temporal Availability					
Rood, (1997)	LITA	Yes	Yes	No	Yes	No	No	No
Hillman and Pool, (1997)	PTAL	Yes	Yes	Yes	No	No	No	No
Schoon et al., (1999)	AI	Yes	Yes	Yes	No	No	No	No
Ryus et al., (2000)	TLOS	Yes	Yes	No	Yes	No	No	No
Polzin et al., (2002)	Time of day based tool	Yes	Yes	No	Yes	Yes	No	No
Kittelson & Associates et al., (2003)	TCQSM	Yes	Yes	Yes	Yes	No	No	No
Bhat et al., (2006)	TAM	Yes	Yes	Yes	Yes	Yes	No	No
Fu and Xin, (2007)	TSI	Yes	Yes	Yes	Yes	Yes	Yes	No
Mamun, (2011)	Composite index	Yes	Yes	No	Yes	No	No	No
Curtis et al., (2012)	SNAMUTS	Yes	Yes	Yes	Yes	Yes	No	No

3 Research Methods

This section includes study area and data sets, empirical analysis and modelling techniques, and deliberation techniques adopted in the research.

3.1 Study Area and Data Sets

To evaluate equity in TODs and in the PT network, the research used five main datasets: Bengaluru housing database for *manuscripts 1* and *3*; HH survey data within the case study area for *manuscripts 1, 2* and *3*; case study area land use data for *manuscripts 1* and *3*; metro user survey data within the case study area for *manuscripts 2* and *3*; and Bengaluru transport service and demand characteristics for *manuscript 4*.

3.1.1 Bengaluru housing database

In order to assess the housing equity in TODs, in *manuscript 1*, the condominiums data (Figure 3) were collected from LJ Hookers, a private real estate firm. This housing database contains only condominiums/multi-family units' data, not informal or single family housing units. The collected condominiums' data include project status, number of units in each project, unit sizes, location, and market value.

The condominiums database includes all the condominiums initiated in a five-year period (2009-2014), 2009 being the year the high density TOD policy was introduced in Bengaluru. Currently, some of the condominiums are in the construction stage, with some being occupied. According to this policy, FAR around metro stations/terminals increased to 4 for all permitted uses, irrespective of the applicable FAR (generally, it varies from 1.7 to 2.4 based on land use) (Government of Karnataka, 2009). Initially, the policy was limited to areas falling within the 150 m radius around transit stations; later it was extended to a 500 m radius following market pressure. The data allow for assessing the equity implications of the new TODs coming up with the advantage of the high density policy. Given that the density bonus is limited to 500 m from station areas, the new high rise houses located within this distance are referred to as 'new build TOD housing'. Based on this data, the location-based housing price and its affordability to various income groups is assessed, in Bengaluru. The analysis reflects the income groups that are being excluded from the coveted TODs. To further understand housing inequities in new TODs,

and their association with new build and old build gentrification and PT ridership, the research conducted a detailed HH survey in a chosen case study area.

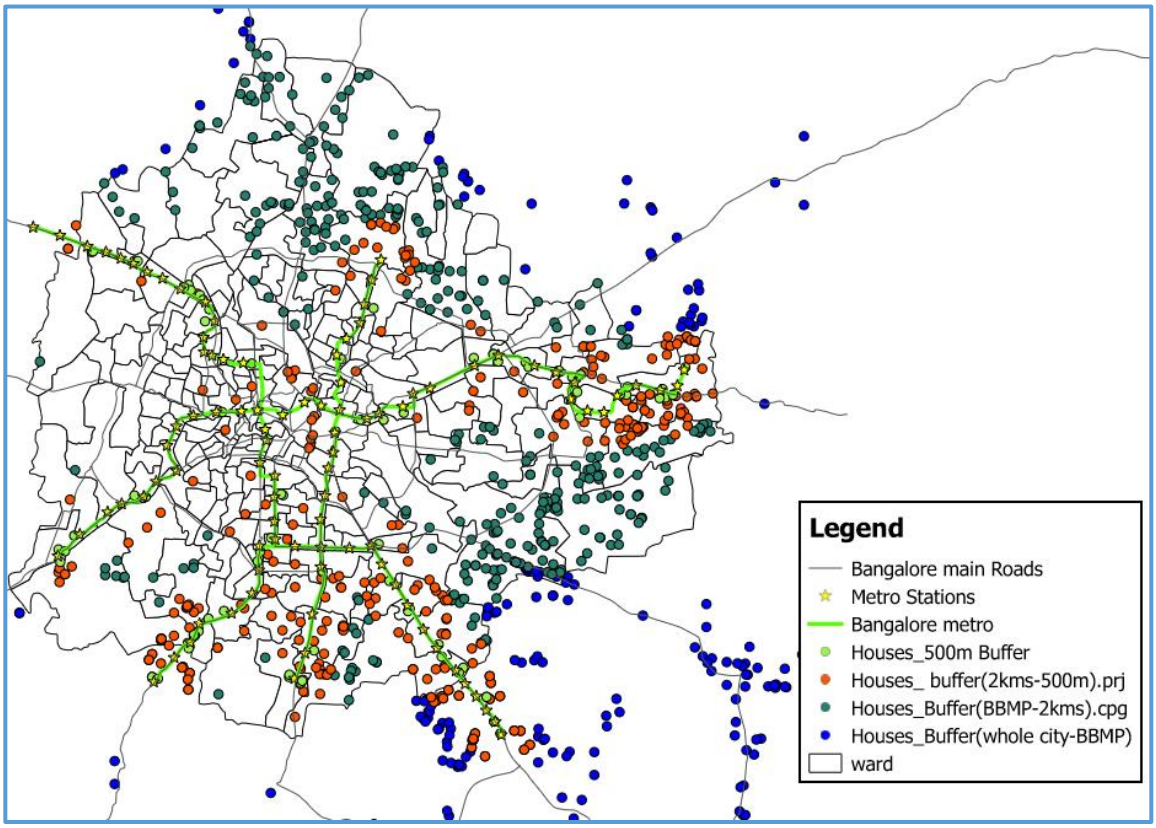

Figure 3: Condominium developments and their location in Bengaluru

3.1.2 Household survey data in the case study area

The case study research focuses on the Yeshwanthpur industrial area, located in a middle suburb of Bengaluru. The case study area boundaries are defined within a half mile radius of PT stations (Great Communities Collaborative, 2007; Dominie, 2012; Guerra et al., 2011). It is often argued that it is the recommended distance in Indian cities, where private vehicle ownership is low and majority of the population depend on public transit for their mobility needs. However, Indian studies clearly show that people do not prefer to walk beyond 10 min/800 m (at a speed of 4.8 km/h) to reach the transit station (Balya et al., 2016, Ramirez and Seneviratne, 1996). According to a study by Advani and Tiwari (2006), more than 92 % of the access trips in Indian cities are within this distance. This could be due to the availability of multiple PT and IPT options.

Before the Bengaluru metro's construction, the Yeshwanthpur industrial area comprised of old build residential area on one side of the metro station; and industrial, vacant and brownfield land on the other (Figure 5). Lately, the side of the industrial, vacant and brownfield land has witnessed high rise newly built TODs (Figure 4). The case study is described in detail in *manuscripts 1* and *2*. Yeshwanthpur industrial area was chosen because it helps demonstrate the new TODs' association with the new build and old build gentrification in TODs, and illustrate the travel behaviour of gentrifiers and non-gentrifiers.

A detailed primary HH survey on socio-economic, housing and travel characteristics was conducted in the case study area, to evaluate the new TODs' association with gentrification and the impact of gentrification on PT ridership. The HH survey questionnaire appears in the appendix, and the sampling techniques and sample size adopted are described in *manuscripts 1* and *2*.

Manuscript 1 uses the HH survey data related to socio-economic and housing characteristics, to evaluate the TOD housing equity and its association with new build and old build gentrification.

Manuscript 2 uses the HH survey data on travel characteristics, to understand the travel behaviour of residents of new build and old build developments and the impact of TOD gentrification on PT ridership. The preliminary analysis of the TOD residents' travel characteristics indicates that most of the PT trips are undertaken by bus and that the metro use among TOD residents is very low, as the metro network is not fully developed yet and serves only a small stretch of around 10 km (at the time of the survey). Only a few HH survey respondents indicated using the metro as a mode of travel. Therefore, the HH survey data were used to assess the impact of gentrification only on bus as a mode of travel. To assess the impact of gentrification on choosing metro as a mode of travel, a metro-user survey was conducted within the metro station premises.

3.1.3 Land use and proposed housing projects data base in the case study area

The case study area's susceptibility to further gentrification due to housing inequity depends upon the affordability of developments under planning, and the land availability for future developments. The land might be vacant, brownfield, industrial, commercial or

residential. To quantify the land availability for future developments, the research attempted to understand the land use type being used (by developers) for new developments. For this, data on existing land use characteristics of the case study area were sourced from Indigo Consultancy in Bengaluru in 2015, and compiled in GIS (Figure 4). The land use characteristics before the construction of new developments in the case study area were gathered using Google Earth and compiled in GIS (Figure 5).

Additionally, to assess how equitable the proposed and under-construction TOD housing are, data on the new projects initiated in 2015 in the case study area, were collected. The data—collected personally at each project's office—include number of units, price, unit size, and project area.

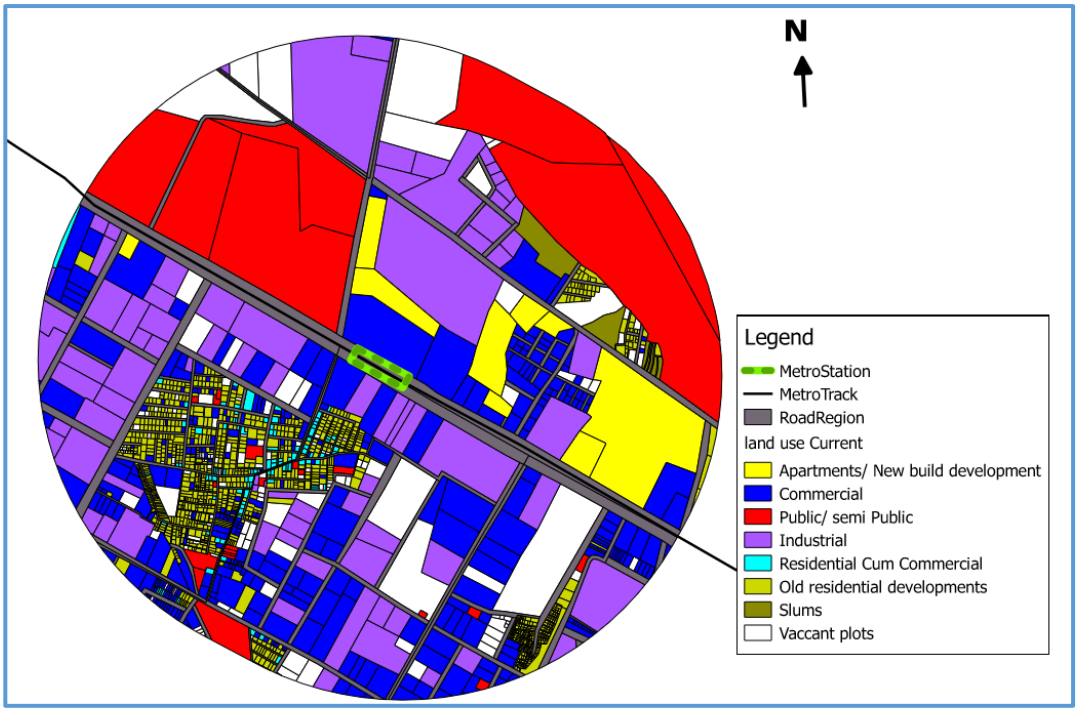

Figure 4: Land use characteristics of the case study area (2015)

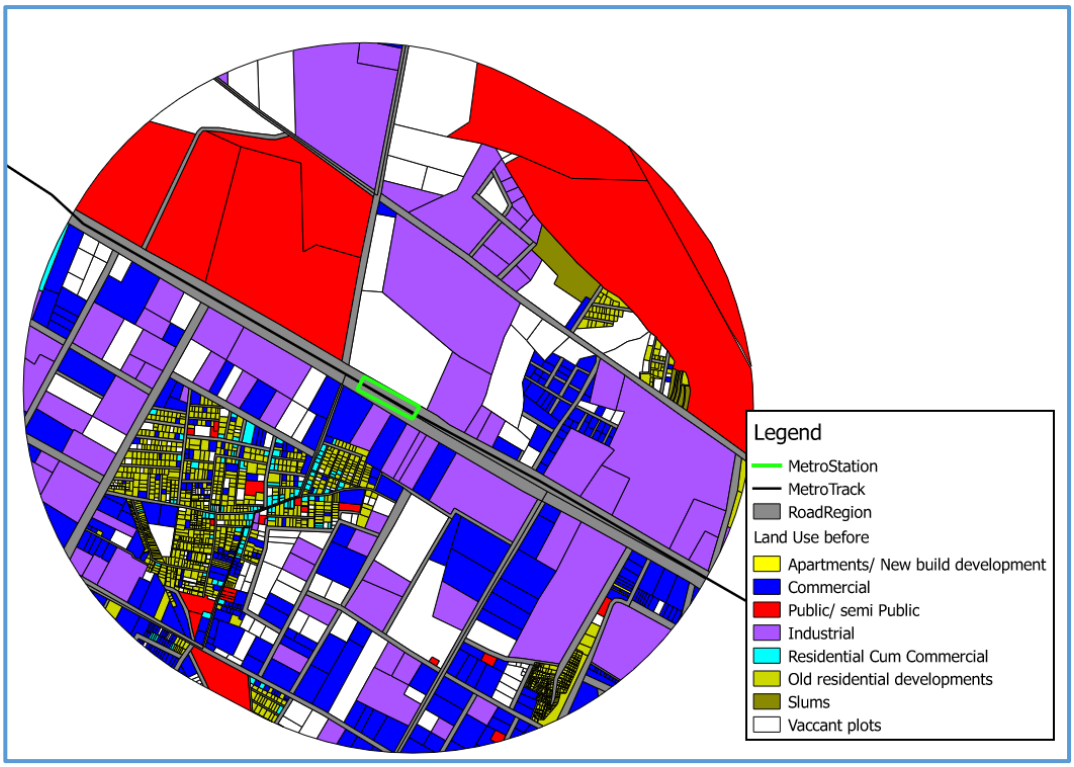

Figure 5: Land use characteristics of the case study area prior to new TODs

3.1.4 Metro user survey

As already mentioned, a metro user survey was conducted in the case study area, to assess the impact of gentrification on choosing metro as a mode of travel. The main objective of the survey was to understand whether the TOD gentrifiers—with high income and a private vehicle—continue using their unsustainable private modes or become PT riders like the economically weaker local residents. The detailed metro user survey questionnaire appears in the appendix; the sample size and survey methods are described in *manuscript 2*.

3.1.5 Bengaluru transport service side and demand side characteristics

In the study, PT network equity is evaluated in terms of its accessibility and affordability. For this, the study uses data on transport service side and demand side characteristics collected from secondary sources. The detailed data collected to evaluate PT equity at network level—which is the focus of *manuscript 4*—along with their sources are highlighted in Figure 6.

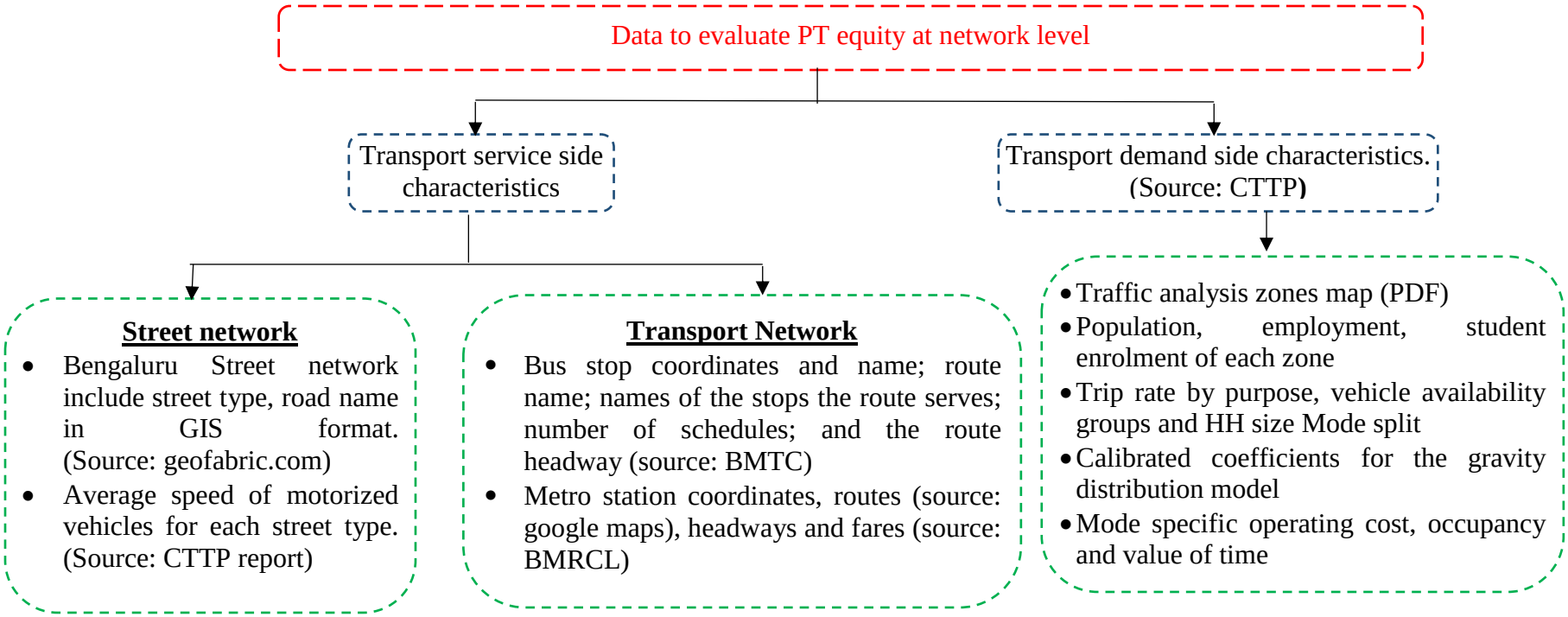

Figure 6: Data sets to evaluate PT network equity

In developed countries, PT agencies are likely to maintain data on transport service side and demand side characteristics in GIS format, thus making the data readily available for assessing TAAI. However, developing countries like India lack proper data management systems. Often the researchers must gather the data from various organisations. This study also relies on data put together based on previous studies, PT agencies' websites, and open sources like Geofabrik.

3.1.5.1 Transport service side characteristics

The Bengaluru street network was downloaded from Geofabrik in GIS format, but the links in the network were not well connected. The network connectivity errors were resolved in Trans-CAD using the option 'check line layer connectivity' (Tools-Map editing-Check line layer connectivity). Once the well-connected street network was achieved, the street characteristics were entered. These include: street type (primary, secondary, tertiary, and connecting street); street name; link length; mode specific speeds; and mode specific travel times. The street characteristics type and name are sourced from the network downloaded from Geofabrik; the link lengths estimated by Trans-CAD based on latitude and longitude; the average speed of motorised vehicles (car, motorbike and auto rickshaw) on each link observed from the Comprehensive Traffic and Transport Plan of Bengaluru (CTTP) based on the respective street type; and the walking speed assumed as 4 kph (RITES, 2011). The bus travel time is assumed as 20% higher than the motorised vehicle travel time of the respective link, to account for the bus dwelling time, as suggested in the CTTP report. The metro speed is considered as 34 Kph (Bangalore Metropolitan Rail Corporation Limited, 2016). Based on the mode specific speed of each link, and link length, the travel time of each mode on each link is calculated.

The PT network is not readily available with the PT agencies. The data on the bus stops and routes are available with Bangalore Metropolitan Transport Corporation Limited (BMTC) in Microsoft Excel (Bangalore Metropolitan Transport Corporation Limited, 2015). The data include: bus stop coordinates and name; route name; name of the stops the route serves; number of schedules; and the route headway. Using this data in TransCAD, selected bus routes are digitised using the route system editing box. The routes are selected based on their average headway. Though there are approximately 1800 active

bus routes in Bengaluru, the analysis includes only those with less than 20 min headway, as these entail a waiting time of around 10 min, which is the most acceptable waiting time of a PT user (Curtis et al., 2012). Out of the 1800 routes, 91 routes—with a frequency of less than 20 min—are identified and digitised in TransCAD along with their route names and average headways. The metro routes and stops are digitized in Trans CAD—with the help of Google Maps—along with their headways, from the Bangalore Metropolitan Rail Corporation Limited (BMRCL) website. The bus and metro system routes are differentiated by mode specific codes. Bus routes are coded as 1 and metro routes as 2. Preparing these datasets into TransCAD compatible data was one of the most time consuming aspects of the research project.

3.1.5.2 Transport demand side characteristics

To evaluate PT equity at the network level, *manuscript 4* weights the service side characteristics (GC between O&D) with the corresponding travel demand. To facilitate this, the mode wise travel demand between various O&D pairs is assessed. To estimate the travel demand, traffic analysis zones (TAZ)/CT must also be digitised (in TransCAD) along with the street and PT network. The centroids of these TAZs are considered the O&D points for all the trips produced in and attracted to (P&A) the corresponding TAZs. The study considers the same TAZs as the CTTP does, as the CTTP report is the only available data source to estimate the travel demand. According to CTTP, there are 191 zones. These zones were digitised in TransCAD using the geocoded TAZ map image extracted from the CTTP report. The zone characteristics—including population, employment, and student enrolment—of each zone, for the base year (2015) and horizon year (2025), sourced from the CTTP, are adopted to assess the travel demand between various zones (191x191). The said data appear in the appendix. The next section describes in detail the model adopted to estimate the mode-based travel demand between each O&D pair.

3.2 Empirical Analysis and Modelling Techniques Applied in the Research

Primarily, two modelling techniques are applied in this research. The first one (in *manuscript 2*) is the binary logistic regression model, to estimate the impact of TOD gentrification on PT ridership. The second one (*in manuscript 4*) is the four step modelling

technique, to estimate the total travel demand and the PT travel demand between various TAZs/O&D pairs, to assess PT equity at the network level. In addition to these modelling techniques, the various empirical analysis techniques employed in the research, to evaluate the equity at the station area and network levels, include housing affordability analysis, sensitivity analysis, and comparative analysis. The above mentioned empirical analysis and modelling techniques are briefly described below, in chronological order of their usage in the thesis.

3.2.1 Housing price and its affordability analysis

To analyse the housing equity of new build TOD housing, the housing price and its affordability to various income groups was analysed and compared with that of the rest of the city (*Manuscript 1*). The affordability of HHs to own a house was derived based on the housing affordability index (HAI). HAI is defined as the ratio of the housing price to the gross annual HH income (Kosareva and Tumanov, 2008; Neill et al., 2008). HAI varies from country to country. In India, HAI for income group of INR (Indian Rupees) 100,000 to 300,000 annual income—referred to as economically weaker section (EWS) and low income group (LIG)—should not exceed 3, and that for income group of annual income above INR 300,000, should not exceed 4 (Jones Lang Lasalle, 2012).

$$\text{Average HH income to own a house} = \text{Housing price}/\text{HAI}$$

3.2.2 Comparative analysis

The comparative analysis technique is adopted in *manuscripts 1* and *2*. *Manuscript 1* employs the technique for two research objectives. The first is to check if the new build TOD housing is leading to any gentrification, by comparing the gentrification indicators (drawn from the literature review) of old and new residential areas. The data on the gentrification indicators are drawn from the HH survey. The second is to assess the case study area's susceptibility to further gentrification, by observing the land on which the new build TOD housing is coming up, through land use comparative analysis before and after new TODs.

Manuscript 2 also employs the comparative analysis technique for two research objectives. The first is to evaluate the influence of socio-economic indicators—underlying gentrification—on metro ridership, by comparing the travel behaviour of gentrifiers with

that of non-gentrifiers, using HH survey data. The second is to evaluate the role of metro on changing travel behaviour of TOD residents, by comparing the travel mode shares of gentrifiers with that of non-gentrifiers, before the metro became operational.

3.2.3 Sensitivity analysis

In order to correlate new TOD housing and gentrification, the sensitivity of choosing new build TOD housing, with regard to gentrification indicators, was plotted. Income, occupation and education were considered predictive variables, and coded as categorical variables. *Manuscript 1* describes, in detail, the coding of the predictive variables. The probability of choosing new build TOD housing, with respect to each predictive variable with the rest of them constant, was plotted.

In *manuscript 2*, the sensitivity of PT use, with regard to the gentrification indicators, was plotted. The gentrification indicators which showed significant impact on PT ridership in the binary logistic regression model were adopted as predictive variables for this analysis.

3.2.4 Binary logistic regression model

The binary logistic regression model was employed for predicting the influence of various socio-economic characteristics—underlying gentrification—on PT ridership among metro station area residents in the Yeshwanthpur industrial area. The model helps understand the cumulative effect of gentrification indicators on PT ridership. The indicators include HH location (new build TOD or old build TOD), motorised vehicle ownership, income, occupation, education, age, house ownership, and gender. The model was developed based on the HH survey data. Since the HH survey captured significantly fewer metro trips than bus trips, the model was used to analyse the influence of gentrification indicators on PT ridership for bus—as a mode of travel—alone, not metro.

According to the binary logistic regression model, the general equations to predict the probability of an event (using PT) to occur are (German, 2007):

$$\pi_i = e^{z_i} \div (1 + e^{z_i})$$

$$\text{logit}(\pi_i) = \ln[\pi_i \div (1 - \pi_i)] = z_i = b_0 + b_1 x_{i1} + b_2 x_{i2} + \ldots\ldots + b_P x_{ip},$$

Where

π_i = The probability of choosing PT (bus)

x_{ij} = The j^{th} predictor for the i^{th} case

b_j = The j^{th} coefficient

p = The number of predictors

Manuscript 2 describes the modelling in detail, including the coding of the predictive variables and the parameters omitted from the analysis.

3.2.5 Travel demand assessment model

Manuscript 4 employs the first three steps of the common four step modelling process to assess the mode-based trips produced in each zone.

3.2.5.1 *Trip generation:* This is the first step of four step modelling and predicts the number of trips P&A to each TAZ.

Trip production: This refers to estimating the number of trips produced in each TAZ. In this study, the trips produced in each zone were estimated based on the cross-classification method in TransCAD. In cross-classification, the members of a TAZ are divided into various homogenous groups. In this study, the HHs in each TAZ were divided into 18 homogenous groups, based on the HH size (1, 2, 3, 4, 5 and 6+ members) and vehicle availability (no vehicle available (NV), car available (Car), and motorbike available (MB)). Different trip rates were assigned to the 18 groups, based on 4 trip purposes (home base work (HBW), home based education (HBE), home based business (HBB), and home based other (HBO)). Table 5 shows the 72 trip rates based on which the trips produced in each TAZ were estimated.

Table 5: Daily person trip rate by purpose, vehicle availability groups and HH size

Purpose	HBW			HBE			HBO			HBB		
HH size/VA	NV	Car	2W	NV	Car	2W	NV	Car	2W	NV	Car	2W
1	0.85	1.39	1.25	0.09	0.02	0.12	0.16	0.75	0.1	0.01	0.14	0.02
2	1.26	2.08	1.29	0.06	0.1	0.04	0.8	1.16	0.87	0.06	0.09	0.12
3	1.62	2.44	1.51	0.28	0.7	0.39	0.83	1.32	0.81	0.11	0.21	0.18
4	1.68	2.67	1.7	0.59	1.15	0.62	0.95	1.54	0.9	0.1	0.21	0.14
5	2.02	3.03	2.09	0.63	1.3	0.72	1.01	1.73	1.01	0.13	0.29	0.17
6+	2.62	4.4	2.77	0.65	1.36	0.71	1.24	2.42	1.32	0.2	0.46	0.26

Source: CTTP report

Once the trips produced in a TAZ were estimated for 72 sub models using the cross classification method, the 6 HH size groups of the respective trip purposes and the vehicle availability groups, were aggregated and converted to 12 (4x3) trip production sub models for each TAZ (four trip purposes and three vehicle availability groups).

Trip attraction: This refers to predicting the number of trips attracted to each zone. Based on the employment, education, and business opportunities of each zone in 2015, the HBW, HBE and HBB trips produced were proportionally distributed among 191 CTs. The HBO trips were proportionally distributed based on the population of each CT.

3.2.5.2 *Trip distribution:* This model is used to predict the spatial pattern of trips or other flows between O&D pairs. The general equation of the travel demand from origin *i* to destination *j* is:

$$T_{ij} = P_i \times A_i \times F(GC_{ij})$$

Where

T_{ij} = Trips estimated from zone *i* to zone *j*

P_i= Production from zone *i*

A_i= Attraction from zone *j*

$F(GC_{ij})$ = Friction factor (cost deterrence) for zone *i* to zone *j*

There are various models to predict the friction factor between O&D pairs using various impedance factors such as travel time, and cost or GC. The study uses the doubly

constrained gravity distribution model with GC as an impedance factor, as shown below. *Manuscript 4* describes in detail the GC calculation and the assumptions adopted.

$$F(C_{\text{ij}}) = GC_{ij}^{X_1} \exp\left(X_2 GC_{ij}\right)$$

Where

GC_{ij} = Generalized cost for zone *i* to zone *j*

X_1, X_2= Calibrated coefficients

The calibrated coefficients for the gravity distribution model were adopted from the CTTP report (Table 6). Using the GC matrix and the calibrated coefficients, the 12 P&A tables were distributed among 191 zones. The 12 O&D matrices were aggregated to obtain over all travel demand between O&D pairs. The total travel demand was adopted to weight the service side characteristics of PT and of its competitive private modes to evaluate PT equity at the network level.

Table 6: Calibrated coefficients for the gravity distribution model

Sub Model	X_1	X_2
HBW NV	-0.84316	-0.02398
HBW Car	-1.02515	-0.02232
HBW 2W	-1.23621	-0.03486
HBB NV	-1.11578	-0.0135
HBB Car	-2.4717	0.02378
HBB 2W	-1.87393	-0.01319
HBE NV	-0.69755	-0.02773
HBE Car	-0.04748	-0.12299
HBE 2W	-1.13519	-0.07329
HBO NV	-0.30219	-0.0349
HBO Car	-1.8974	-0.03161
HBO 2W	-0.60915	-0.09566

Source: CTTP report

3.2.5.3. *Mode split models:* According to CTTP, each trip purpose and vehicle availability group has different mode shares. Hence, to obtain the mode wise O&D matrix, the 12 O&D matrices were distributed among various modes based on their respective mode shares (Table 7) and the O&D matrices of the respective modes were aggregated. Amongst

the 4 O&D matrices (car, motorbike, auto rickshaw and PT), the study adopted only the PT O&D matrix to estimate the impact of the proposed PT plans on improving PT performance.

Table 7: Mode share distribution by trip purpose and vehicle availability

Sub model/mode	**Car+ taxi**	**Motor bike**	**Auto**	**PT**
HBW NV	1.599521	6.532471	5.748563	86.11945
HBW Car	31.41293	45.22029	2.04304	21.32374
HBW 2W	1.582913	66.59906	1.88849	29.92954
HBE NV	5.238118	2.909968	7.03396	84.81795
HBE Car	16.25792	31.81225	9.049752	42.88008
HBE 2W	8.723452	24.55423	10.34827	56.37405
HBB NV	1.287628	7.391683	10.83	80.49069
HBB Car	38.8771	40.2401	5.341427	15.54136
HBB 2W	1.511708	69.2981	6.105482	23.08471
HBO NV	0.633145	1.51124	17.47883	80.37679
HBO Car	31.40335	12.48363	23.74686	32.36616
HBO 2W	1.013147	18.03619	27.46136	53.4893

Source: CTTP report

In addition to these models, to evaluate TOD inequities at the network level, the study developed its own tool called TAAI. *Manuscript 4* discusses this tool in detail. In addition to these empirical analysis techniques, the study adopted a stakeholder deliberation technique to identify the strategies to mitigate the TOD inequities. This technique is highlighted in the next section.

3.3 Stakeholder Deliberation Techniques

There is a range of techniques under the 'deliberative' umbrella. Out of these techniques, the current research adopts the 21st century dialogue deliberation technique to facilitate stakeholder collaboration towards identifying strategies to address TOD inequity issues in the case study area. This technique was preferred because, unlike other methods, it has the ability to reflect the collective view of all the stakeholders in a short span of time (Hartz-Karp, 2005). In this advanced technique, small groups of stakeholders and deliberation-facilitation teams are connected through networked computer software, which helps facilitators to quickly summarise the participants' inputs, find common ground, and

prioritise the complex issues on-board (Hartz-Karp et al., 2013). Further, it enables display of results in real time for cross verification, and minimises any possible manual errors in data collection and analysis.

The stakeholders who participated in the deliberation included representatives from various organisations (that are involved in TOD planning) and the community in the case study area. The detailed methodology adopted to facilitate the stakeholder deliberation is described in *Journal paper 3*.

4 Overview of *Manuscript 1*: Evaluating Equity in TODs

The existing literature on gentrification in TODs emphasises the fact that PT accessibility and TOD amenities increase land and rental values in TODs. On one hand, these raised values work in the favour of the PT agencies, who capture these monetary gains—using innovative financial tools—to finance PT infrastructure. On the other hand, the increase in land and rental values—from ignoring the equity aspects while planning—can exclude and replace the poor, who are more dependent on PT, from the coveted TOD areas (Reconnecting America et al., 2007). This issue of gentrification in TODs has always bothered equity advocates who are often reluctant regarding PT investments. But transport planners tend to accept the equity issue as a collateral damage of the PT investments (Pollack et al., 2010). Transport planners and equity advocates must appreciate the symbiotic relationship between PT and those dependent on it, and act together to incorporate equity objectives into TOD planning.

Manuscript 1 focuses on evaluating the equity aspects in TODs, which is the initial step in incorporating equity objectives into TOD planning. The study illustrates this step through the case study of Bengaluru, India. To evaluate the equity aspects in the new TODs in the case study area, the study first assesses the new TODs' housing price and affordability to various income groups and compares them with that of the rest of the city. Next, the study focuses on the Yeshwanthpur industrial area, evaluating the association of new TODs with gentrification. Further, the susceptibility to gentrification in future is evaluated.

4.1 New Build TOD Housing Price and its Affordability

The assessment of the new build TODs' housing price and affordability indicates that on an average, these TODs are 68% costlier than the housing located in adjacent similar suburbs, away from the PT stations. The minimum price of new build TOD housing units is INR 2.5 million. Most of these units are priced in the range of INR 5 to 7.5 million (Figure 7). The minimum HH income to own a house in TODs is 0.6 million per annum (assuming the affordability index of 4), which is much higher than Bengaluru's average annual income, which is INR 0.15 million (RITES, 2011). As for the housing size, irrespective of the location, all the new developments are larger in size than the affordable

unit size (which is generally less than 60 sq.m) for EWS and LIG (Ministry of Housing and Urban Poverty Allevation, 2009; 2013).

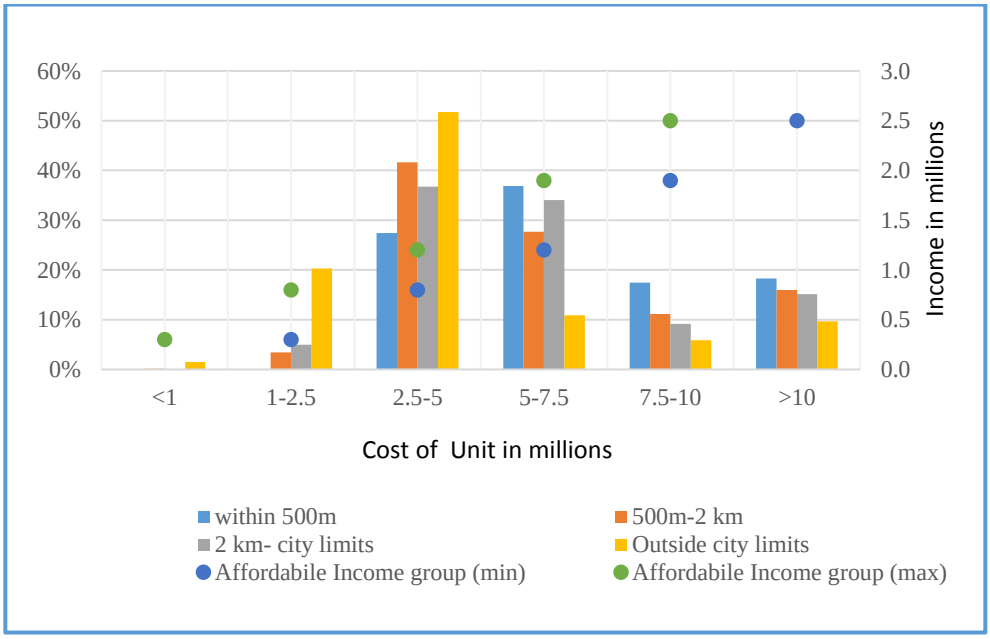

Figure 7: Condominium price comparisons in INR and mapping of affordable income groups to own a house, by location

These data analyses demonstrate that new build high density housing opportunities for the poor are sparse in the city, and sparser around the PT stations. The single family units and informal units are likely to continue to be built across the city, including in TOD locations, but there is no available data to assess the affordability of these units. For further understanding of the association of new TODs with gentrification, a case study area analysis was conducted.

4.2 Gentrification in New Build and old Build TODs

To evaluate TOD housing's association with gentrification, the study adopted a comparative analysis of gentrification indicators, and a sensitivity analysis of choosing new TOD housing with regard to gentrification indicators.

The comparative analysis demonstrates that new TOD area residents are significantly wealthier, more professional, better educated, and own—on an average—one car per family. The sensitivity analysis also presents a clear positive correlation between choosing new build TOD housing and, occupation, income and education. However, the old build

traditional area's socio-economic indicators are similar to those for average Bengaluru residents (RITES, 2011). The analysis results illustrate that the new build high rise TOD housing are undergoing new build gentrification, but the old build traditional areas are not being gentrified yet.

4.3 Predicting Susceptibility to Further Gentrification

The susceptibility to further gentrification has been determined through a comparative analysis of land before and after new TODs came up. It shows that there is a lot of scope for further development of the study area, due to the availability of large parcels of vacant and industrial area. This is reinforced by the review of the housing projects in the planning stage, in the study area, in 2015. The prices of the housing units in these projects fall in the range of INR 25 million to 136 million. Evidently, many income groups will be excluded from occupying the new build TOD housing.

In sum, *manuscript 1* illustrates that new TODs are being occupied entirely by the affluent while the poor are being excluded. However, there are no apparent plans to remove or redevelop the old residential area, which offers substantial PT benefits to its residents, now that they live adjacent to the metro. The influx of wealthy residents contributes to the TOD areas' economic sustainability by generating jobs for the poor (chauffeurs, cooks, and domestic help) and improves the local economy. Nevertheless, the trend of encouraging the influx of only wealthier residents may eventually shut out those with lower incomes from these areas. This will keep the poor from using the affordable PT, unless housing authorities and PT agencies step in to prevent the large scale urban renewal-type development in the area or include affordable and small size housing in these new build developments (Feinstein and Allen, 2008).

5 Overview of *Manuscript 2*: Impact of TOD Inequities on PT ridership

Manuscript 1 illustrates that the new TOD developments are being occupied by affluent car owners and are excluding the poor who are more dependent on PT (Chava et al., 2016a). *Manuscript 2* evaluates the impact of this social inequity in TODs on PT ridership in Yeshwanthpur industrial area.

To analyse the impact of TOD gentrification on PT ridership, the study adopted various empirical analysis techniques. The first is a comparative analysis of the travel behaviour of new TODs' (gentrifiers) and old TODs' residents (non-gentrifiers). The second is a binary logistic regression model study to quantify the impact of gentrification on PT ridership in TODs, along with a sensitivity analysis to predict the influence of key gentrification parameters on PT mode choice. Finally, a comparative analysis of mode shares of gentrifiers and non-gentrifiers before metro operations began, was conducted to illustrate the influence of metro on TOD residents' travel mode shares.

5.1 Travel Behaviour of Gentrifiers vs. Non-gentrifiers

The comparative analysis of the travel behaviour of gentrifiers vs. non-gentrifiers indicates that the bus and NMT mode shares are lower and private vehicle mode share is significantly higher among gentrifiers than among non-gentrifiers. Surprisingly, the metro mode share is higher among gentrifiers than among non-gentrifiers. To further understand the cumulative impact of the gentrification indicators on PT ridership, the binary logistic regression model is adopted.

5.2 Influence of Gentrification Indicators on Choice of PT (≈bus) Mode

As highlighted in Table 8, the binary logistics regression model—to determine the influence of gentrification indicators on PT ridership—demonstrates that the probability of survey respondents staying in old residential areas (non-gentrifiers) using PT is almost twice of that of the respondents from the new residential areas (gentrifiers). The sensitivity analysis shows a negative correlation between the PT usage and the predictive variables of income and vehicle ownership. This may be attributed to the low level of service (LOS) offered. The influence of gentrification indicators on metro (as a mode of travel) might vary, as metro offers high speed travel and comfort, comparable to private vehicles. This

is further studied through a metro user survey aimed at assessing the metro's influence on travel behaviour of gentrifiers and non-gentrifiers.

Table 8: Binary logistic regression model to predict the likelihood of commuting by PT (≈bus) with respect to various socio-economic characteristics

Predictive variable	B	SE	Wald	Significance	Odds ratio
Settlement code	0.562	0.274	4.234	0.039	1.754
Sex	0.539	0.182	8.793	0.003	1.715
Vehicle per HH	−1.502	0.297	25.588	0.000	0.223
HH income	0.336	0.109	9.436	0.002	0.715
Constant	−1.601	0.513	9.739	0.002	0.202

Note: HH income categories are 1 = < INR 300,000; 2 = INR 300,000 to 750,000; 3 = INR 750,000 to 1,500,000; 4 = > INR 1,500,000. Model summary: N = 659 (df = 4); χ^2 = 88.4; significance = 0.000.

Source: Author's compilation based on HH survey data

5.3 Metro Influence on Travel Behaviour

To analyse the impact of the metro on changing travel patterns of TOD residents, the mode shares before the metro were studied. The analysis indicates that the metro has significantly altered the travel behaviour of gentrifiers and non-gentrifiers (Figure 8). It has not only attracted bus and auto users, but also private vehicle users, including car and motor bike users. However, 80% of the respondents travel to a destination within walkable distance from the PT stations. This reflects that though the metro, unlike buses, can attract gentrifiers, it is unlikely to succeed effectively if the destination is not within walkable distance from the PT stations. This may be attributed to poor and expensive last mile connectivity (LMC). Literature indicates that the preferable walking distance in Indian conditions is 800 m to 1 km and the preferable cycling distance is 2.5 km to 4.8 km (Advani and Tiwari, 2006; Ramirez and Seneviratne, 1996; Tiwari and Jain, 2008). Improving the bicycle infrastructure for safe access to the metro can increase the catchment area by 3 to 5 times. To improve the catchment beyond the ambit of NMT, the metro needs to be integrated with other travel modes. These LMC measures can attract more gentrifiers and non-gentrifiers from the private modes of travel.

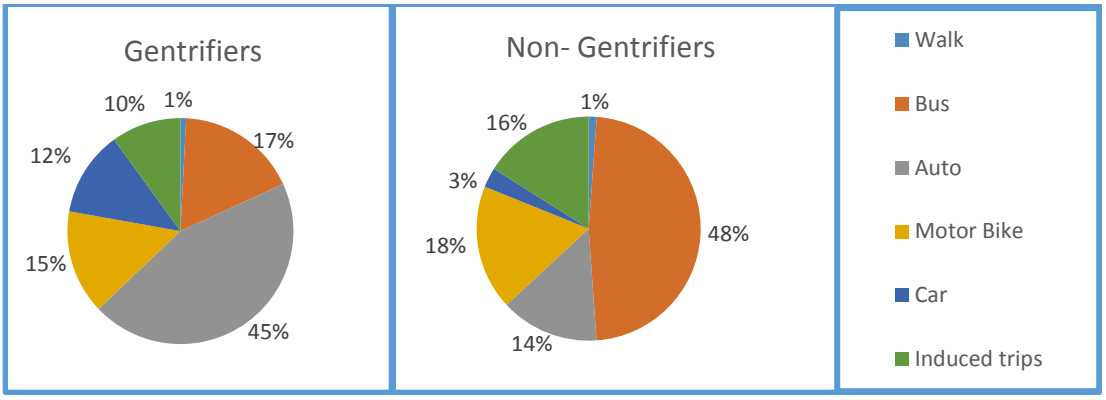

Figure 8: Metro user's mode of travel before the metro

Though gentrifiers are contributing to PT ridership, the assessment of the willingness—of both gentrifiers and non-gentrifiers—to use the metro after the fully integrated metro network is developed, indicates that the probability of non-gentrifiers choosing PT is higher than that of gentrifiers. Bus and intermediate public transport (IPT) users—among both gentrifiers and non-gentrifiers—are more willing to choose the metro (if the fares are similar) than private mode users. Although some gentrifiers expressed willingness to use the metro in the future, the probability of them shifting to the metro is lower than that of the non-gentrifiers.

Based on the findings discussed above, the study recommends that for realising the benefit of sustainable transport, TOD density policy must be balanced with equity considerations by incorporating affordable housing policies to accommodate people with low income and low vehicle ownership rate and needs to introduce uniform fare structure for all PT modes. This will not only mitigate the equity concerns facing TODs but also contribute significantly to PT ridership, as the willingness of the people in this category to use the metro, is higher than that of the affluent residents in these developments.

6 Overview of *Journal paper 3*: Framework for Stakeholder Deliberation towards Developing Inclusive Housing Strategies for Equitable TODs

Manuscript 1 clearly demonstrates that the new high rise developments in TODs are creating social inequity by excluding the poor from the coveted TODs (Chava et al., 2016a). Though gentrifiers contribute to PT ridership (*manuscript 2*), the probability of non-gentrifiers choosing PT is higher, as they lack access to private vehicles (Chava et al., 2016b). Towards addressing the TOD equity issues as well as increasing PT ridership, *Journal paper 3* proposes a framework for a stakeholder deliberation, towards developing inclusive housing strategies.

A stakeholder deliberation provides participants with meaningful opportunities to engage in a dialogue and share their views. This process transforms the stakeholders' role in the traditional planning process, from combative and divisive to cooperative and collaborative (Hartz-Karp, 2007). It generates community-wide buy-in and enhances the odds of stakeholders supporting the goals of inclusive TODs and the corresponding strategies being implemented (Jillella et al., 2015; Machell et al., 2009).

Though some developed countries' cities have affordable housing strategies in place (Shoemaker, 2006), these strategies may not be applicable to developing countries like India due to vast socio-economic, land use and legislation disparities (Reconnecting America, 2013; 2014). Each TOD is unique, and with different opportunities and challenges for inclusive TOD housing development. Hence, the study proposes a three level stakeholder deliberation framework towards identifying inclusive housing strategies suited to the local context.

The first level in the stakeholder deliberation framework involves **informing** the stakeholders about: existing policies and their implementation; neighbourhood characteristics; and existing inclusive housing strategies and best practices for potential local strategies. The second level is **involving** the stakeholders in identifying the issues affecting the implementation of the affordable housing policies in TODs. The final level is **collaborating** with the stakeholders to identify strategies—to address the issues

identified at the previous level—suited to the local context. The steps at each level of engagement are highlighted in Figure 9.

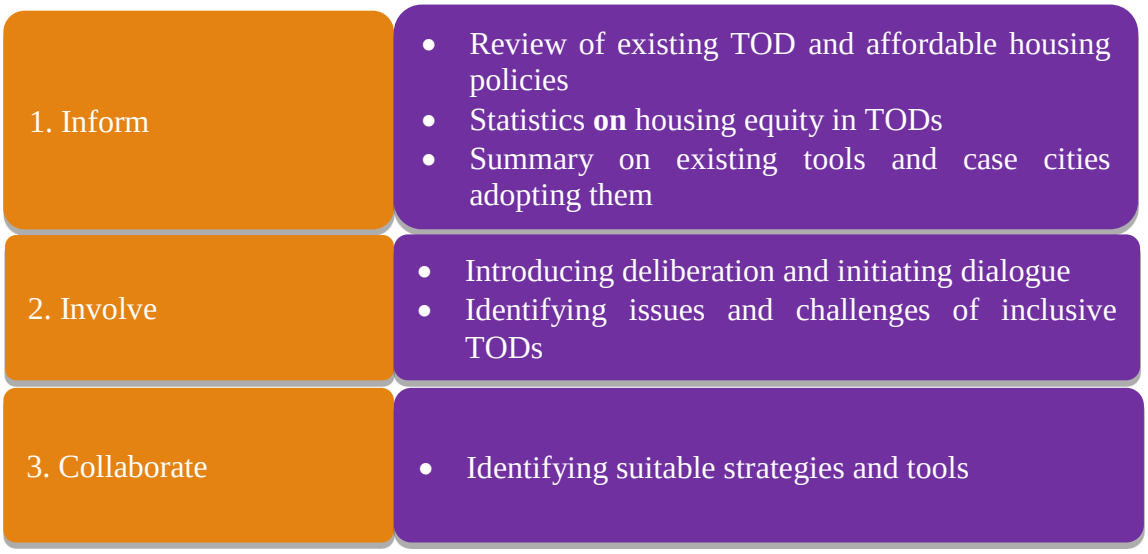

Figure 9: Proposed three level stakeholder deliberation framework to develop affordable housing strategies

The proposed three-level stakeholder deliberation framework developed in the study, is applied in the context of the Yeshwanthpur industrial area metro station, Bengaluru to identify affordable housing strategies in TODs towards equitable and sustainable TODs. The deliberation was conducted at Bengaluru and involved about 80 participants, including representatives from a wide range of organisations, and the community. In the first level of engagement, the stakeholders were *informed* about:

- existing housing polices applicable to the case study area;
- housing inequities (*Manuscript 1)*;
- land use characteristics (*Manuscript 1)*;
- impact of housing inequity on PT ridership (*Manuscript 2)*; and
- affordable housing strategies and tools adopted in developed countries, along with the best practices (Literature review)

In the second and third level of engagement, the 21st century dialogue deliberation technique was adopted to *involve* stakeholders in identifying the challenges in incorporating affordable housing in TODs, and to *collaborate* with them to come up with

strategies to combat each identified challenge. The results section summarises the outcomes of the stakeholder deliberation.

The deliberation, conducted as a part of the study, is the first attempt in Bengaluru to bring all the stakeholders—involved in TOD planning—to a common platform to discuss the equity issues in TODs. The response has been positive and the involved stakeholders remain committed to implement the identified strategies. However, the implementation process is a long-term one and merits further stakeholder deliberation. The proposed framework can be modified (according to the deliberation's objectives) and extended to future deliberations.

The proposed framework for stakeholder deliberation can be applied to any TOD, to facilitate inclusionary housing processes towards a more inclusive and sustainable TOD.

7 Overview of *Manuscript 4*: Evaluating and Incorporating Equity in PT Network Planning

To incorporate equity in PT network planning, we must ensure accessible and affordable PT services throughout the city. However, the existing PT performance evaluation measures focus only on accessibility aspects, neglecting affordability. Such planning and evaluation may lead to inequalities, especially in the developing world, where PT affordability is a significant factor in choosing PT as the mode of travel. A PT system may be accessible but not affordable if the fares are higher than those of other modes, and an affordable PT system may not be accessible, if it involves higher travel times (Arora and Tiwari, 2007; Cervero, 2011). Users often weight the travel time and cost, and compare with the competitive modes while choosing their mode of travel (Lesley, 2001). *Manuscript 4* proposes a composite tool called TAAI to evaluate the PT performance of each TAZ. TAAI expresses PT performance by comparing it with that of alternative competitive modes of travel, and can be evaluated using any macro level planning software.

The proposed tool can help provide answers to two questions:

Q1. How accessible and affordable is the present PT system in comparison with alternatives (car/motorbike)?

Q2. How does proposed upgrading of the PT system improve the accessibility and affordability of PT services?

7.1 The Accessibility and Affordability of the Current PT System in Comparison with that of the Alternative Modes

To evaluate the TAAI of the current PT system, *manuscript 4* proposes a three step method.

Step 1: Selecting zone size and time period of the day, for evaluating the TAAI:

TAAI evaluates PT performance at zone level. The smaller the zone size, the better is the TAAI. The study recommends choosing block level data—rather than CT level—for each time period of the day, for evaluating the TAAI, if all the required data sets highlighted in the research methods are available.

Step 2: Assessing PT availability of zones through spatial and temporal accessibility analysis:

The measure of PT availability of a zone reflects if PT can at all be considered a potential mode choice in that zone during that period of the day. Evaluation of the PT availability of a zone involves choosing the acceptable waiting time and walking time/distance, selecting the PT routes with acceptable frequencies (double the average waiting time), and creating a buffer of acceptable walking time/distance around each identified route stop. The area within the buffer indicates the PT service area (Horner and Murray, 2004). The zones whose centroids fall within the PT service area are chosen for the evaluation.

Step 3: Assessing PT accessibility and affordability through TAAI:

To evaluate the PT accessibility and affordability of zones, the study adopts all three accessibility components (spatial, temporal and network) and PT fares. The accessibility component of PT and private vehicles is expressed in terms of travel time from one zone to another. Travel time in the case of PT include access time, egress time, waiting time, transfer time, and in-vehicle travel time. To assess affordability, the study considers PT fares for PT; and operating cost (including wear and tear), toll price, and parking price, for private vehicles. Each component of PT travel time is weighted with the user's perception, to evaluate the total user perceived PT travel time from one zone to another. The PT fares and private vehicle travel costs are converted into time using the value of time (VOT) of the respective user. The time and fares are aggregated to derive the GC of each mode for each O&D pair. The TAAI for each O&D pair is expressed as the percentage by which the GC of PT travel is higher or lesser in comparison with the GC of travel by alternative competitive modes, for that O&D pair. Generalising the TAAI for each zone includes weighting an O&D pair's TAAI with the pair's travel demand, aggregating the weighted TAAI of each O&D pair of the trip origin's zone, and dividing the weighted TAAI of each zone by the number of trips produced in that zone.

7.2 Impact of Proposed Upgrading of the PT System on PT Performance

The impact of PT upgrading plans on improving accessibility and affordability of PT is evaluated in two ways *(Manuscript 4*):

Quality of the current and proposed PT system compared with alternatives: To assess the impact of the proposed PT, we estimate the TAAI of the existing and proposed PT systems taken together, using the steps highlighted above.

Assessing percentage of savings in PT GC: The savings in PT GC can serve as a basis for policymakers to decide on future PT plans for their cities. The study proposes a mathematical equation to evaluate the percentage of savings in each zone's PT GC, achieved due to the proposed upgraded PT system.

The proposed tool is administered in Bengaluru, India—using TransCAD—to illustrate the value of the TAAI. In Bengaluru, the tool is adopted to evaluate the performance of bus transport and the influence of metro on PT performance. The analysis results indicate that out of 191 zones in Bengaluru, 30 zones do not fall in the PT service area. The bus routes' TAAI analysis indicates that people in these zones incur significantly higher GC in bus than in motorbike and car travel. The combined bus and metro TAAI reflects that the metro has not improved spatial availability, as most of the metro routes are along existing bus routes. However, owing to its higher speed, the metro competes with the motorbike and car to an extent, especially in zones close to the metro station. Additionally, the introduction of the metro has reduced the average GC of PT by almost 15%.

The proposed TAAI tool can be administered by any city to evaluate how the city PT is serving its residents. It can also help to scientifically identify the new routes and new PT systems to improve PT quality, and quantify their impact on PT performance. It can also facilitate a way to determine PT fares based on the travel cost of competitive modes.

8 Summary of Results

The research illustrates the framework to evaluate and incorporate equity objectives in PT planning at the station area and network levels. This section summarises the key findings of this research. *Manuscript 1* demonstrates that the housing units in the new TODs cost 68% more than the houses located in the suburbs. Due to high price and larger unit sizes, the new TODs are excluding the poor, providing housing only for the affluent, thus undergoing new build gentrification. The residents of these new TODs are wealthy, highly qualified professionals with a high vehicle ownership rate. However, the data also illustrate that the new TODs have not yet impacted the old build traditional areas, due to the difficulty in amalgamation of small plots and the availability of vacant plots. Thus, the classic old build gentrification which was prevalent in USA and Europe is not yet observed in the case study area. This may change once all the available vacant land has undergone construction.

Table 9: Size and average selling price of condominiums, by location.

Location	Cost in INR /sq. Meter	1 BHK	2 BHK	>2 BHK
Within 500 Meters (% of to outside city limits)	62000 (68%)	3%	42%	55%
500 Meters to 2 KM (% of to outside city limits)	56000 (51%)	3%	36%	61%
2 KM to city limits (% of to outside city limits)	52000 (41%)	8%	34%	58%
Outside city limits	37000	8%	39%	53%

Manuscript 2 illustrates the implications of the aforementioned TOD gentrification on PT ridership. It indicates that gentrification indicators correlate negatively with bus as a mode of travel, due to its low LOS. However, the trend is changing with the metro as a mode of travel due to the comfort, convenience, and travel time savings it offers. The study clearly demonstrated that gentrifiers are contributing significantly to metro ridership and willing to give up their private vehicle once the fully integrated network is developed. However, the probability of non-gentrifiers—who do not have access to personal vehicles—shifting to metro is higher than that of gentrifiers. Hence, for a functional, fair and equitable TOD neighbourhood, and for further increasing PT ridership, the study recommended that the

new TODs include housing priced at 30% of the average monthly income of the neighbourhood's old residents.

Towards facilitating inclusive housing in new TODs, *Journal paper 3* proposed a three level stakeholder deliberation framework and applied it to the case study area. In the first level, information was provided to the stakeholders regarding the case study area (from *manuscripts 1* and *2*). In the second level of the stakeholder deliberation, challenges in implementing affordable housing in TODS were identified. In the third level, the stakeholders deliberated upon each of the identified challenges, to determine their individual solution(s), based on the information presented at the beginning of the deliberation. The identified challenges and strategies to incorporate affordable housing in TODs for equitable and sustainable TODs are summarised in Figure 10 (Chava and Newman, 2016).

Figure 10: Identified challenges for inclusive housing in TODs and suitable solutions/strategies to combat the challenges

At the network level, to evaluate equity, *manuscript 4* proposed a composite PT performance measure called the TAAI. The index is applied to Bengaluru and

recommendations are provided towards enabling PT network equity. The case study area analysis shows that the GC incurred in bus travel—and also in combined bus and metro travel—is higher than that in travel by alternatives. The results, in terms of percentage by which the PT GC is higher than that of alternatives, are summarised in Table 10 (Chava et al., 2016d).

Table 10: Number of zones and their TAAI range (Percentage by which PT GC is higher compared with competitive mode)

	TAAI with respect to motorbike		**TAAI with respect to car**	
	Bus system	Bus and Metro system	Bus system	Bus and Metro system
0-50%	0	0	6	76
50-100%	2	70	93	63
100-150%	39	57	57	19
150-200%	108	28	5	3
200-250%	10	4	0	0
>250%	32	32	30	30
Sum	191	191	191	191

The results indicate that after the introduction of the metro, the percentage by which PT users' GC is higher than that of competitive mode users, has reduced substantially. However, the combined metro and bus network GC continues to be higher than that of the private vehicles. Hence, the study recommended improving the PT accessibility and affordability by creating a well-integrated PT network (includes fare integration) towards equitable and sustainable PT for all urban area residents.

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9 Conclusions and Recommendations for Future Work

9.1 Conclusions

The overarching research question this thesis sought to answer is:

'How can equity objectives be incorporated in transit oriented development planning and public transport network planning, to achieve a more equitable public transport system particularly in the developing world?'

To address the various aspects of this question, different research aims were identified. How each research aim is addressed and the conclusions drawn from each, are summarised below:

1. ***Quantifying the equity aspects in TODs***

   To evaluate the equity aspects in TODs, *manuscript 1* analysed the housing inequities in TODs and their association with various forms of gentrification, and the susceptibility to future gentrification. The results illustrate that TODs are undergoing new build gentrification, thus creating inequity issues. Based on the analysis results, the study concludes that TOD policies should include affordable housing policies to reduce gentrification in new TODs, towards functional, fair and equitable TODs.

2. ***Quantifying the impact of TOD inequities on PT ridership***

   To evaluate the impact of TOD inequities on PT ridership, the influence of gentrification indictors on PT as a mode of travel is evaluated and the travel behaviour of gentrifiers and non-gentrifiers is compared (*Manuscript 2)*. The results illustrate that accommodating people from LIG and EWS—with low vehicle ownership—can significantly contribute to the PT ridership. Hence, the study concludes that affordable housing must be incorporated in new developments not only to ensure equity but also towards reaping significant sustainable transport benefits.

3. ***Developing a stakeholder deliberation framework towards enabling equity in TODs***

   Equitable and sustainable TODs can be achieved by accommodating all income groups in station areas. To incorporate affordable housing in TODs, cities must identify and implement various affordable housing strategies, suited to the local

context. The study proposes a framework for conducting a stakeholder deliberation towards collaborating with the stakeholders in identifying such locally-suited strategies. The framework is illustrated in the case of the Yeshwanthpur industrial area through a stakeholder deliberation conducted as a part of the study (*Journal paper 3)*. The deliberation highlighted that implementing inclusive housing regulations, setting up SPV and land banking entities, developing local area plans in collaboration with the community and monitoring the affordable housing implementation process and outcomes are effective strategies to enable equity in the case study area.

With this deliberation, the stakeholders realised the strength of the deliberation technique in shaping inclusive and sustainable TODs, and are committed to implement the identified strategies. To audit the implementation process and outcomes, the research methods developed in *manuscript 1* and *manuscript 2* could be used.

4. ***Developing a tool to quantify the equity aspects of the PT network***

Quantifying the PT network equity aspects involves an evaluation of the network's accessibility and affordability for all the city residents. The study developed a tool called TAAI to facilitate this (*Manuscript 4*). The TAAI tool allows a unique opportunity to evaluate PT quality by aggregating cost and travel time components into GC, comparing PT GC with that of its competitive modes of travel, and assessing the impact of new transit proposals on PT quality.

The tool can be applied to any city to evaluate PT equity, and can help scientifically identify new routes, and assess their impact on PT quality. It can also facilitate a way to determine PT fares based on the travel cost of competitive modes.

5. ***Administering the tool in the case study area and providing recommendations for equitable PT at the network level***

The developed tool was applied in Bengaluru to evaluate the PT network equity and the impact of the proposed metro on improving PT equity. The results illustrate that the metro has improved PT equity to an extent. For further improvement, the study recommends improving walkways and cycle paths, introducing placemaking at PT stops (as in Hong Kong), and implementing mode integration measures including fare integration (Ahluwalia et al., 2014; Bertolini and Spit, 1998).

9.2 Recommendations for Future Work

The thesis identifies several research areas which merit further research. The research methods adopted in this research can guide future research on the identified areas, listed below.

Future research question 1

How does a new PT system and its associated developments impact neighbourhood equity, for various TOD typologies?

Manuscript 1 illustrates the implication of new TODs for a working class neighbourhood. To understand how new TODs would impact a different neighbourhood, further research could consider classifying the station areas typologically, vis-à-vis neighbourhood location, density, land use characteristics, socio-economic status of the residents, real estate market, and redevelopment opportunities. Following the approach employed in *manuscript 1*, the equity for each typology can be evaluated.

Future research question 2

How do gentrification indicators impact metro as a mode of travel, in the case of Delhi?

The Bengaluru metro network is not fully developed, which could be the reason why only a small number of the HH survey respondents claimed using the metro as a mode of travel. This number was insufficient to model the cumulative effect of various gentrification indicators on metro as a mode of travel. However, the Delhi metro has come a long way and can lend itself to a case study to illustrate the influence of gentrification indicators on metro as a mode of travel, and the role of metro in changing travel behavior.

Future research question 3

How do temporal fluctuations in service side and demand side characteristics impact PT performance?

Due to the lack of data for each time period of the day, the study evaluated the accessibility and affordability on an average day, based on average values of the demand side and service side characteristics. Since this data is available in developed countries, the TAAI

can be evaluated during each time period of the day, in most developed cities. This helps evaluate the sensitivity of PT performance with regard to temporal fluctuations in the service side and demand side characteristics and will be a better test of the tool.

Future research question 4

What are the innovative strategies to provide accessible and affordable PT at the network level through stakeholder deliberation?

Following the three level deliberation framework employed in *Journal paper 3*, future research should consider conducting stakeholder deliberation among transport operators (including bus, metro and IPT operators, and NMT associations). Stakeholder deliberation helps identify suitable strategies for well-integrated accessible and affordable PT for all urban area residents. The community engagement could go further and use the approaches outlined by Hartz-Karp (2007) to show how to involve a random sample of citizens to enable a more deliberative democracy approach to such policy development.

The thesis has indicated that upgrading PT and the use of TODs to help restructure the city in a less car dependent way, is gaining popularity as governments are under pressure to do much more. Enabling grassroots engagement in policy is likely to improve the chances of a more inclusive and equitable PT system.

10 References

Advani M and Tiwari G (2006) Bicycle – As a feeder mode for bus service. In: VELO MONDIAL conference, Cape Town, South Africa, pp. 1–8.

Ahluwalia IJ, Kanbur R and Mohanty PK (2014) Urbanisation in India: Challenges, Opportunities and the Way Forward. SAGE Publication, India.

Arora A and Tiwari G (2007) A Handbook for Socio-economic Impact Assessment (SEIA) of Future Urban Transport (FUT) Projects. Transportation Research and Injury Prevention Program (TRIPP), Indian Institute of Technology, New Delhi.

Arrington G. and Cervero R (2008) Effect of TOD on Housing, Parking, and Travel. Washington D.C.

Atkinson R (2000) Measuring Gentrification and Displacement in Greater London. Urban Studies, 37(1), 149–165.

Balya MI, Katti BK and Saw K (2016) Spatial Transit Accessibility Modeling of Indian Metropolitan City in Gis Environment. International Journal for Traffic and Transport Engineering, 6(1), 51–62.

Bangalore Metropolitan Rail Corporation Limited (2016) Available from: www.bmrc.co.in.

Bangalore Metropolitan Transport Corporation Limited (2015) Available from: mybmtc.com.

Belzer D, Bernstein S, Gorewitz C, et al. (2006) Preserving and Promoting Diverse Transit-Oriented Neighborhoods. Report, Center for Trnasit Oriented Development: A collaboration of the Center for Neighborhood Technology, Reconnecting America, and Strategic Economics.

Benson N (2010) A Tale of Two Cities: Examining the Success of Inclusionary Zoning Ordinances in Montgomery County, Maryland and Boulder, Colorado. Journal of Gender, Race & Justice, 13(3), 753–777.

Bertolini L and Spit T (1998) Cities on Rail. Spon Press, London.

Bhat C, Bricka S, Mondia J la, et al. (2006) Metropolitan Area Transit Accessibility Analysis tool. Report, National Center for Transportation Research, University of South Florida. Report no: 0-5178-P3.

Bourne LS (1993) The Myth and Reality of Gentrification : A Commentary on Emerging Urban Forms. 30(1), 183–189.

Brown KD (2001) Expanding Affordable Housing Through Inclusionary Zoning : Lessons from the Washington Metropolitan Area. The Brookings Institution Center on Urban and Metropolitan Policy, Washington, DC.

Calavita N, Grimes K and Mallach A (1997) Inclusionary housing in California and New Jersey: A comparative analysis. Housing Policy Debate, 8(1), 109–142, Available from: http://www.tandfonline.com/doi/abs/10.1080/10511482.1997.9521249.

Center for Transit-Oriented Development (2009) Mixed-Income Housing Near Transit: Increasing Affordability With Location Efficiency. Washington D.C, Available from: tod-201-mixed-income-housing-near-transit-increasing-affordability-with-location-efficiency.

Cervero R (1993) Ridership Impacts of Transit-Focused Development in California. The University of California Transportation Center, Berkeley.

Cervero R (1994) Transit-based housing in California: evidence on ridership impacts. Transport Policy, 1(3), 174–183, Available from: http://linkinghub.elsevier.com/retrieve/pii/0967070X94900132.

Cervero R (2007) Transit-oriented development's ridership bonus: a product of self-selection and public policies. Environment and Planning A, 39(9), 2068–2085, Available from: http://www.envplan.com/abstract.cgi?id=a38377 (accessed 22 April 2015).

Cervero R (2010) Transit Transformations: Private Financing and Sustainable Urbanism in Hong Kong and Tokyo. In: Ascher W and Krupp C (eds), Physical Infrastructure Development: Balancing the Growth, Equity and Environmental Imperatives, New York: Palgrave Macmillan, pp. 165–185.

Cervero R (2011) State Roles in Providing Affordable Mass Transport Services for Low - Income Residents. In: International Transportation Forum, 25- 27 May, Leipzig, Germany.

Cervero R and Kockelman K (1997) Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon, 2(3), 199–219.

Cervero R and Murakami J (2009) Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Studies, 46(10), 2019–2043.

Chapple K (2009) Mapping Susceptibility to Gentrification : The Early Warning Toolkit. Berkeley, CA: Center for Community Innovation.

Chatman DG (2013) Does TOD Need the T? Journal of the American Planning Association, 79(1), 17–31, Available from: http://www.tandfonline.com/doi/abs/10.1080/01944363.2013.791008 (accessed 2 May 2014).

Chava J and Newman P (2016) Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit Oriented Developments. Sustainability, 8(10).

Chava J, Newman P and Tiwari R (2016a) Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore. Curtin University Sustainability Policy Institute, Curtin University, Perth, WA.

Chava J, Newman P and Tiwari R (2016b) Gentrification of station areas and its impact on transit ridership. Curtin University, Perth, WA.

Chava J, Newman P and Tiwari R (2016c) Transit Accessibility and Affordability Index: A tool to evaluate transit quality. Curtin University, Perth, WA.

Curtis C, Scheurer J and Mellor R (2012) Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS). Report for European Cooperation in Science and Technology.

Danyluk M and Ley D (2007) Modalities of the New Middle Class: Ideology and Behaviour in the Journey to Work from Gentrified Neighbourhoods in Canada. Urban

Studies, 44(11), 2195–2210, Available from: http://usj.sagepub.com/cgi/doi/10.1080/00420980701520277 (accessed 14 July 2014).

Davidson M (2007) Gentrification as global habitat: a process of class formation or corporate creation? Transactions of the Institute of British Geographers, 32(4), 490–506, Available from: http://doi.wiley.com/10.1111/j.1475-5661.2007.00269.x.

Davidson M and Lees L (2005) New-build gentrification and London's riverside renaissance. Environment and Planning A, 37, 1165–1190.

Dominie W (2012) Is Just Growth Smarter Growth ? The effect of Gentrification on Transit Ridership and Driving in Los Angele's transit station area Neighborhood. University of California, Berkley.

Feinstein BD and Allen A (2008) Article Community Benefits Agreements with Transit Agencies : Neighborhood Change Along Boston's Rail Lines and a Legal Strategy for Addressing Gentrification. Transportation law Journal, 38(85), 85–114.

Freeman L and Braconi F (2004) Gentrification and Displacement. Journal of the American Planning Association, 70(1), 39–52.

Fu L and Xin Y (2007) A New Performance Index for Evaluating Transit Quality of Service. Journal of Public Transportation, 10(3), 47–69.

German R (2007) Lecture Notes on Generalized Linear Models. Available from: http://data.princeton.edu/wws509/notes/.

Glass R (1964) Introduction: Aspects of Change. In: London : MacGibbon & Kee: Macgibbon & Kee.

Government of Karnataka (2009) Amendment to the zoning regulations of master plan of Bangalore. UDD 93 MNJ 2008, India.

Grube-cavers A and Patterson Z (2015) Urban Rapid Rail Transit and Gentrification in Canadian Urban Centres – A Survival Analysis Approach. Urban studies, 50(1), Available from: https://www.cirrelt.ca/DocumentsTravail/CIRRELT-2013-06.pdf.

Guerra E, Cervero R and Tischler D (2011) The Half-Mile Circle: Does It Best Represent Transit Station Catchments? Report, Institute of Transportation Studies, University of California, Berkeley.

Hackworth J and Smith N (2001) The changing state of gentrification. Tijdschrift voor Economische en Sociale Geografie, 92(4), 464–477, Available from: http://doi.wiley.com/10.1111/1467-9663.00172.

Hartz-Karp J (2005) A case study in deliberative democracy: Dialogue with the city. Journal of Public Deliberation, 1(1), 1–15.

Hartz-karp J (2007) How and Why Deliberative Democracy Enables Co-Intelligence and Brings Wisdom to Governance How and Why Deliberative Democracy Enables Co-Intelligence and. Journal of Public Deliberation, 3(1), Available from: http://www.publicdeliberation.net/jpd/vol3/iss1/art6.

Hartz-Karp J, Gollagher M and Weymouth R (2013) Sustainability through deliberative Democracy. Workbook, Curtin University Sustainability Policy Institute, Perth.

He S (2010) New-Build Gentrification in Central Shanghai: Demographic Changes and Socioeconomic Implications. Population, Space and Place, 361(July 2009), 345–361.

He S (2012) Two waves of gentrification and emerging rights issues in Guangzhou, China. Environment and Planning A, 44(12), 2817–2833, Available from: http://epn.sagepub.com/lookup/doi/10.1068/a44254 (accessed 11 May 2016).

Hendricks SJ, Winters P, Wambalaba F, et al. (2005) Impacts of Transit Oriented Development On Public Transportation Ridership. Report, Center for Urban Transport reserach, University of South Florida, Tempa: National Research council, washington, D.C.

Hillman R and Pool G (1997) GIS-based Innovations for modeling public transport accessibility. Traffic Engineering and Control, 38(10), 554–559.

Horner MW and Murray AT (2004) Spatial representation and scale impacts in transit service assessment. Environment and Planning B: Planning and Design, 31(5), 785–797, Available from: http://www.envplan.com/abstract.cgi?id=b3046 (accessed 17 October 2014).

Jillella S, Matan A and Newman P (2015) Participatory Sustainability Approach to Value Capture-Based Urban Rail Financing in India through Deliberated Stakeholder Engagement. Sustainability, 7(7), 8091–8115, Available from: http://www.mdpi.com/2071-1050/7/7/8091/ (accessed 19 August 2015).

Jones Lang Lasalle (2012) Affordable Housing in India: An Inclusive Approch to Sheltering the Bottom of the Pyramid. Report, New Delhi.

Kahn ME (2007) Gentrification Trends in New Transit-Oriented Communities : Evidence from 14 Cities That Expanded and Built Rail Transit Systems. Real Estate Economics, 35, 155–182.

Katz B and Sawyer N (2003) Rethinking Local Affordable Housing Strategies: Lessons From 70 Years of Policy and Practice. The Brookings Institution Center on Urban and Metropolitan Policy and The Urban Institute, Washington, DC.

Kittelson & Associates, Urbitran, LKC Consulting Services, et al. (2003) A guidebook for developing a transit performance- measurement system. TCRP report 88, TRB, Washington, D.C., Available from: http://gulliver.trb.org/publications/tcrp/tcrp_report_88/ Guidebook.pdf.

Knaap GJ, Ding C and Hopkins LD (2001) Do Plans Matter?: The Effects of Light Rail Plans on Land Values in Station Areas. Journal of Planning Education and Research, 21(1), 32–39, Available from: http://jpe.sagepub.com/cgi/doi/10.1177/0739456X0102100103 (accessed 27 May 2014).

Kniech BR and Pollack M (2010) Making affordable Housing at Transit a ReaBest Practices in Transit Agency Joint Development Affordable Housing Best Practices in Transit Agency Joint Development. Report, FRESC: Good Jobs, Strong Communities and Enterprise researched.

Kosareva N and Tumanov a. (2008) Assessing Housing Affordability in Russia. Problems of Economic Transition, 50(10), 6–29, Available from: http://mesharpe.metapress.com/openurl.asp?genre=article&id=doi:10.2753/PET1061-1991501001 (accessed 5 May 2014).

Kushto ER and Schofer JL (2008) Travel and Transportation Impacts of Urban Gentrification: Chicago, Illinois Case Study. Northwestern University, Evanston, Illinois.

Land M Van Der, Curley A and Eijk G Van (2012) Gentrification and Neighbourhood Change. In: International Encyclopedia of Housing and Home, Elsevierr Ltd., pp. 275–279, Available from: http://dx.doi.org/10.1016/B978-0-08-047163-1.00594-4.

Lees L, Slater T and Wyly EG (2008) Gentrification. Routledge, New York: New York: Routledge.

Lesley L (2001) Generalised Costs and the Value of Time as a Method of Patronage Forecasting. Acta Technica Jaurinensis, 2(1), 57–68.

Levy DK, Comey J and Padilla S (2006) Keeping the Neighborhood Affordable: A Handbook of Housing Strategies for Gentrifying Areas. Report, The urban Institute, Washington, D.C.

Lin J (2002) Gentrification and Transit in Northwest Chicago. Journal of Transport Research Forum, 56(4), 175–191.

Litman T (2005) Impact of Rail Transit on the Performance of a Transport System. Transportation Research Record 1930, Transportation Research Board, 23–29.

Litman T (2013a) Affordable-Accessible Housing In A Dynamic City Why and How To Increase Affordable Housing Development In Accessible Locations. Report, Victoria Transport Policy Institute, Canada.

Litman T (2013b) Evaluating Transportation Equity Guidance For Incorporating Distributional Impacts in Transportation Planning. World Transport Policy &Practice, 8(2), 50–65.

Litman T and Brenman M (2012) A New Social Equity Agenda For Sustainable Transportation. Report, Victoria Transport Policy Institute, Canada.

Loukaitou-Sideris A (2010) A New-found Popularity for Transit-oriented Developments? Lessons from Southern California. Journal of Urban Design, 15(1), 49–68, Available from: http://www.tandfonline.com/doi/abs/10.1080/13574800903429399 (accessed 16 April 2014).

Lund H (2006) Reasons for Living in a Transit-Oriented Development, and Associated Transit Use. Journal of the American Planning Association, 72(3), 357–367.

Lund H, Cervero R and Willson RW (2004) Travel Characteristics of Transit-Oriented Development in California. Report, The University of California Transportation Center, Berkeley.

Machell E, Reinhalter T and Chapple K (2009) Building Support for Transit-Oriented Development : Do Community-Engagement Toolkits Work ? Berkeley, CA: Center for Community Innovation.

Mamun S (2011) Public Transit Accessibility and Need Indices : Approaches for Measuring Service Gap. University of Connecticut.

Manaugh K (2013) Incorporating issues of social justice and equity into transportation planning and policy. PhD thesis,School of Urban planning, McGill University, Canada.

McIntosh J, Turbka R and Newman P (2013) Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. Transportation Research - Part A, 67, 320–339.

Mckibbin M (2011) The influence of the built environment on mode choice – evidence from the journey to work in Sydney. In: Australasian Transport Research Forum 2011, Adelaide, Australia, pp. 1–12.

Ministry of Housing and Urban Poverty Allevation (2009) Guidelines for Interest Subsidy Scheme for Housing the Urban Poor (ISHUP). New Delhi, Available from: http://mhupa.gov.in/w_new/ISHUPGuidelines.pdf.

Ministry of Housing and Urban Poverty Allevation (2013) Affordable housing in partnership Scheme guidelines. Government of India, New Delhi, Available from: http://mhupa.gov.in/W_new/AHP_23_09_2013.pdf.

Mixed-Income Transit-Oriented Development (2016) Available from: www.mitod.org (accessed 31 May 2015).

Muley DS (2011) Evaluating the Transport Impacts of Transit Oriented Developments (TODs). PhD thesis, School of Urban Development, Faculty of Built Environment & Engineering, Queensland University of Technology.

Murphy L (2008) Third-wave Gentrification in New Zealand: The Case of Auckland. Urban Studies, 45(12), 2521–2540, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097106 (accessed 11 May 2016).

National Urban Transport Policy (2001) Report, Directorate of Urban Land Transport, New Delhi.

Neill PO, Johnston K, Phibbs P, et al. (2008) Housing Affordability Literature Review and Affordable Housing Program Audit. Urban Research Center, University of Western Sydney, Sydney, Available from: www.uws.edu.au/__data/assets/pdf_file/0004/164623/landcom_report_2008-07-21.pdf.

Nelson AC (2003) Top Ten State and Local Strategies to Increase Affordable Housing Supply. Housing Facts and Findings, 5(1).

Newman K and Wyly E (2006) The right to stay put, revisited: Gentrification and resistance to displacement in New York city. Urban Studies, 43(1), 23–57, Available from: http://usj.sagepub.com/cgi/doi/10.1080/00420980500388710.

Newman P and Kenworthy J (1999) Sustainability and Cities: Overcoming Automobile Dependence. Island Press, Washington, DC.

Newman P and Kenworthy J (2015) The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning. Washington D.C: Island Press.

Pollack S, Bluestone B and Billingham C (2010) Maintaining Diversity In America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change. Dukis Center for Urban and Regional policy, Northeastern University.

Polzin S, Pendyala R and Navari S (2002) Development of time-of-day–based transit accessibility analysis tool. Journal of Transportation Research Board, TRB, National Research Council,Washington D.C., 1799, 35–41.

Pucher J and Renne JL (2003) Socioeconomics of Urban Travel: Evidence from the 2001NHTS. Transportation Quarterly, 57(3), 49–77.

Quigley L (2010) Preserving Affordable Housing Near Transit: Case Studies from Atlanta, Denver, Seattle and Washington, D.C.

Ramirez A and Seneviratne P (1996) Transit route design applications using Geographic Information Systems. Transportation Research Record 1305, 123–139.

Reconnecting America (2013) An Equitable TOD Typology for the Atlanta Region.

Reconnecting America (2014) User's Guide TOD Classification Tool.

Reconnecting America, Center for Community Innovation and Non-Profit Housing Association of Northern California (2007) Transit-Oriented for All : The Case for Mixed-Income Transit-Oriented Communities in the Bay Area. Berkeley, CA: Center for Community Innovation, Available from: http://communityinnovation.berkeley.edu/Publications.

Renne JL (2014) TOD Index TM. Report, University of New Orleans, Available from: www.TODindex.com.

Rérat P, Söderström O, Piguet E, et al. (2010) From Urban Wastelands to New-Build Gentrification : The Case of Swiss Cities. POPULATION, SPACE AND PLACE, 10(16), 429–442.

Rérat P, Söderström O and Piguet E (2010) New Forms of Gentrification: Issues and Debates. POPULATION, SPACE AND PLACE, 10(16), 335–343.

RITES (2011) Comprehensive Traffic & Transportation plan for Bengaluru. Report for Karnataka Urban Infrastructure Development and Finance Corporation, Bengaluru.

RITES (2012) Implementation of Commuter Rail System for Bangalore Draft Report. Report for Directorate of Urban Land Transport, Government of Karnataka, Bengaluru.

Rood T (1997) Local Index of Transit Availability- An Implementation Manual. Report for Local Government Commission, Sacramento, California.

Ryus P, Ausman J, Teaf D, et al. (2000) Development of Florida's transit level-of-service indicator. Transportation Research Record 1731, 123–129.

Schoon JG, McDonald M and Lee A (1999) Accessibility indices: Pilot study and potential use in strategic planning. Transportation Research Record 1685, 29–38.

Shoemaker D (2006) Tools for Mixed-Income TOD. Report for Center for Transit Oriented Development, Available from: www.reconnectingamerica.org/assets/Uploads/tools.pdf.

Smith N (1982) Gentrification and Uneven Development. Economic Geography, JOUR, Clark University, 58(2), 139–155, Available from: http://www.jstor.org/stable/143793.

Smith N (1996) The New Urban Frontier: Gentrification and the Revanchist City. London and New York: Routledge.

Song W and Zhu X (2011) Gentrification in Urban China under Market Transformation. International Journal of Urban Sciences, 14(2), 152–163, Available from: http://www.tandfonline.com/doi/abs/10.1080/12265934.2010.9693673 (accessed 11 May 2016).

Suzuki H, Iuchi K and Cervero R (2013) Transforming cities with transit: Transit and Land-Use Integration for Sustainable Urban Development. Washington DC: World Bank.

The city of Atlanta (2005) Beltline Tax Allocation District Ordinance. 05-O-1733, Georgia.

Tiwari G (2011) Key Mobility Challenges in Indian Cities. In: International Transport Forum, 18-20 May, Leipzig, Germany.

Tiwari G and Jain H (2008) bicle in india-IUT-himani.o.pdf. IUT Journal, 59–68.

Topalovic P, Carter J, Topalovic M, et al. (2012) Light Rail Transit in Hamilton: Health, Environmental and Economic Impact Analysis. Social Indicators Research, 108(2), 329–350, Available from: http://link.springer.com/10.1007/s11205-012-0069-x (accessed 10 June 2014).

Tsietsi Monare P, Kotzé N and Morton McKay T (2014) A second wave of gentrification: The case of Parkhurst, Johannesburg, South Africa. Urbani izziv, 25(Supplement), S108–S121, Available from: http://urbani-izziv.uirs.si/Portals/uizziv/papers/urbani-izziv-en-2014-25-supplement-008.pdf (accessed 11 May 2016).

Van Gent WPC (2013) Neoliberalization, Housing Institutions and Variegated Gentrification: How the 'Third Wave' Broke in Amsterdam. International Journal of Urban and Regional Research, 37(2), 503–522, Available from: http://doi.wiley.com/10.1111/j.1468-2427.2012.01155.x (accessed 11 May 2016).

Visser G and Kotze N (2008) The State and New-build Gentrification in Central Cape Town, South Africa. Urban Studies, 45(12), 2565–2593, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097104 (accessed 31 March 2014).

Walker S (2013) The Handbook of Design for Sustainability. Illustrate. Walker S and Giard J (eds), A&C Black.

Wegmann J and Chapple K (2014) Hidden density in single-family neighborhoods: backyard cottages as an equitable smart growth strategy. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 7(3), 307–329, Available from: http://www.tandfonline.com/doi/abs/10.1080/17549175.2013.879453#.VPpF98aIlKo.

Weinberger R, Kaehny J and Rufo M (2010) U.S. Parking Policies : An Overview of Management Strategies. Report, Institute for Transportation and Development Policy, New York.

Wyly E. and Hammel DJ (1999) Islands of decay in seas of renewal: housing policy and the resurgence of gentrification. Housing Policy Debate, 10(4), 711–771.

Yan S, Delmelle E and Duncan M (2012) The impact of a new light rail system on single-family property values in Charlotte, North Carolina. Journal of Transport and Land Use, Available from: https://www.jtlu.org/index.php/jtlu/article/view/261.

11 Manuscripts

Manuscript 1: Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore

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Writing and completion of manuscript, established methodology, data analysis, preparation of tables and figures.

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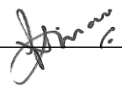

Professor Reena Tiwari, Co-Supervisor

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Gentrification in New Build and Old Build Transit Oriented Developments: The case of Bengaluru

Abstract:

Significant building of Metro systems across Indian cities has begun. The improved transit accessibility in station areas is creating a new market for high rise housing. This paper tests whether the influx of these capitals are creating gentrification in transit oriented developments (TOD) in the city of Bengaluru. The findings indicate that new build TOD housing is gentrifying the station areas with 68% higher price than the suburbs, but the old build existing housing remains ungentrified. The paper suggests policy interventions for inclusive TODs in the new build areas and strategies to maintain traditional communities in the old build areas.

Introduction

Around the world cities are rapidly switching transport and land use priorities to build around fast, high quality rail systems (Newman and Kenworthy, 2015). The Planning Commission in India has mandated all cities with a population in excess of 3 million to start constructing Metro rail transit projects and above 2 million to start planning (Planning Commission, 2013). Bengaluru, the fourth most populous city in India, with a population around 8.5 million, is constructing a metro with a total estimated budget of INR 400 billion. Currently in Bengaluru, metro is operating for a stretch of 32 km and a further stretch of 83 km is under construction (Bangalore Metropolitan Rail Corporation Limited, 2016).

Further to it, with the objective of increasing transit ridership and to generate revenue, Bengaluru is embracing transit oriented developments (TOD). By definition, TOD stands for enabling compact, mixed land use, and non-motorized transport (NMT) outcomes within the 500m to 800m radius of centrally located transit stations (Cervero and Kockelman, 1997). TODs can reduce the need to travel, improve transit and NMT ridership, and reduce private vehicle usage (Cervero and Kockelman, 1997).

In Bengaluru, as part of TOD implementation, the floor area ratio (FAR) is increased to 4 for all permitted uses, irrespective of the applicable FAR (generally varies from 1.7 to 2.4 depending upon the land use) in the areas which fall within 500 m from the metro stations (Government of Karnataka, 2009) .

The huge public transit infrastructure investments combined with favorable zoning regulations are attracting high capital investments near transit stations. As a result, development near stations is occurring at much higher densities and they are witnessing the development of high rise structures, especially in suburbs where the waste vacant lands are available. However, despite policies encouraging inclusive housing, there are no regulations and incentives for the provision of affordable housing in these new high rise housing complexes. Due to the lack of an affordable housing implementation mechanism, these developments may often exclude the poor from highly desirable TODs.. Further these developments may also attract gentrifiers to the existing housing stock and displace the existing residents. Though it is a major concern, unfortunately Indian cities have not focused on this issue. In developed countries, though there are studies on gentrification issues in TODs, they are mostly focusing on social upgradation of neighborhood and did not documents the reason beyond it and the displacement consequences. The aim of this paper is to bridge this gap in the Bengaluru context.

Firstly, the study analyzes the housing characteristics of newly emerging residential complexes in station areas after introduction of zoning incentives and assesses their affordability to various income groups based on the housing affordability index (HAI). Secondly, to understand whether the new developments are creating any gentrification issues in TODs, a case study is undertaken to examine the change in the socioeconomic characteristics of transit neighborhoods. In addition, a sensitivity model is developed to quantify the influence of socioeconomic characteristics on choosing new build TOD housing. Finally, the susceptibility to further gentrification in the case study area is assessed based on a land use analysis.

Prior to analysis, the study starts with the literature review, which includes gentrification and its evolution, followed by the study's significance and the review of the studies specifically related to the gentrification issues in TODs. The second section includes a description of data collection. The third section analyses new build high rise TOD housing

prices and their association with gentrification issues, and assesses susceptibility to future gentrification. Finally, conclusions are drawn.

Gentrification and its evolution

Defining gentrification is a complex process, as its definition is evolving. Glass (1964) defined gentrification as a process through which working-class central city areas are changed through the influx of middle classes and, eventually, the displacement of working classes. However, with social transformation and urban reforms and on-going economic globalization, its definition has been progressively evolving (Song and Zhu, 2011).

The evolutionary process of gentrification, since the mid-20th century, is classified into four phases/waves based on agents of transformation, type of space and the type of displacement. The first wave of gentrification was sporadic, isolated in small central city neighborhoods and and the result of influx of people it is in line with Glass's definition (1964). The second wave was anchored gentrification. It is the result of the revitalization of dilapidated properties by promoters and private investors (inflow of the capitals) in the city centers where the disinvestment has taken place in the past (Rérat, Söderström, Piguet, et al., 2010). These two waves of gentrification take the form of classic gentrification which involves direct displacement of the poor in the city centers.

The developed countries where the inner city areas were neglected in early 20th century such as in UK, USA, South Africa, Australia have undergone this form of gentrification in the latter part of the 20th century (Atkinson, 2000; Freeman and Braconi, 2004; Tsietsi Monare et al., 2014). Countries like India, where the core areas of most cities has remained for the wealthy, the investments were taking place in the booming peripheries and in the satellite towns, and they are not susceptible to these two forms of gentrification yet (Ghertner, 2014).

In the mid-1990s, post-recession, a new (third) wave of gentrification has emerged. This third wave of gentrification is anchored by state-led urban and housing reforms often linked with large scale capital investments. This wave travelled globally and expanded to different sites all over the world (Hackworth and Smith, 2001; Murphy, 2008; Rérat et al., 2010; Van Gent, 2013; Visser and Kotze, 2008). Furthermore, gentrification has moved outside the inner city areas. This contemporary gentrification is diversified and can take

various forms: the classic form (direct displacement); new build gentrification (new developments on brownfield/vacant land for the middle class, excluding the poor); super gentrification (a subsequent wave, replacing the middle class with an elite group); and managed gentrification (where the state maintains a balance among income groups) (Davidson, 2007; Davidson and Lees, 2005; Land et al., 2012). Lastly, the fourth wave is identified in the US after the brief economic crisis in 2001. According to Lees et al., (2008) this latest wave coincided with the financial transformation of housing combined with the consolidation of pro-gentrification policies and polarized urban policies.

Different countries, cities and neighbourhoods may experience different phases of gentrification, varying in form and time frame depending upon the agent (influx of capital/people), their socio-economic system and cultural background. The type and extent of the displacement due to the gentrification also varies from place to place (Zuk et al., 2015).

In countries like India, land availability in the inner city areas is limited and land amalgamation is a difficult task. As a result, large capital investments on housing are pouring in the peripheral areas, satellite towns and Brownfield sites. These investments often follow huge public infrastructure investments, especially in the transportation sector, such as roads, metros and rail lines. Though the developments on vacant and brownfield sites may not lead to direct displacement of pre-existing residents as classic gentrification does, they may still lead to exclusionary displacement, change in social composition and indirect displacement of the poor due to price shadowing, and can lead to new build gentrification (Cameron, 2003; Ellen and O'Regan, 2011; He, 2010). Further, these large investments can attract gentrifiers and displace the poor from their traditional residential area, and trigger third wave or classic gentrification, hereafter referred to as old build gentrification. The current study intends to understand if any such new and old build gentrification is taking place around transit stations as a result of high public and private investments combined with zoning incentives in the case study area of Bengaluru.

Study Significance:

Investments in transit and TODs are gaining momentum across the globe to address transportation and rapid urbanization issues. These investments channelize the urban

growth in a sustainable form around a centrally located rail or bus station. The urban revitalization combined with improved transit accessibility and TOD incentives such as density bonuses, minimum parking, and tax exemptions are attracting large scale capital investments into TODs. As a result of these huge public and private investments, most of the TODs are witnessing high land values (Dziauddin, 2009; Fan and Guthrie, 2012; Kahn, 2007; Knaap et al., 2001; Lin, 2002; McIntosh et al., 2013; Newman and Kenworthy, 2015).

Given the high land values, if there is no affordable housing implementation mechanism, the developments could lead to either old build gentrification (displacement) or new build gentrification (exclusion) (Center for Transit Oriented Development, 2007, 2009). The influx of wealthy residents can contribute to transit ridership and improving neighborhood status and local economy (Cervero, 1994; Cervero, 2007; Chava et al., 2016). However, these highly desirable TODs need to be available to all economic strata for a functional, fair city. The presence of low income people helps to keep an organic sense of place and provides multiple services to the area without generating traffic. Hence, for sustainable TOD planning there is a need to focus on inclusive TODs.

To address these gentrification issues in TODs and to reduce the transportation cost burden for poor people, various cities are adopting transit location as a strategy for the provision of affordable housing. The integration of affordable housing and affordable transportation enables reduction of both housing and transportation costs, which often consume two-thirds of household (HH) income for poor people. For example, Hong Kong TODs. Land constraints, rapid urbanization and deteriorating quality of life prompted the officials in Hong Kong to embrace TODs. Transit and government are actively participating in implementing TOD projects. Government is providing exclusive development rights above and adjacent to station areas to transit agencies at “before rail” prices. The transit agencies selling these development rights to the highest bidder at “after rail” prices and also negotiating a share in future property developments. The active participation of these agencies in real estate activities combined with government land ownership facilitate sustainable, inclusive TOD developments. Currently in Hong Kong 40% of housing in TODs are public and subsidized, and 62% of transit revenues are from

real estate activities (Cervero and Murakami, 2009; Cervero, 2010)**.** Similar projects have happened in Singapore (Newman and Matan, 2013).

Second example to showcase inclusive TOD is Bogota. The high speed bus rapid transit (BRT) is operating in the city since 2000. The city is successfully integrating the affordable housing close to high speed bus rapid transit stations. In Bogota, 22% of the population live in slums located in peripheral areas with few public transit services. As of 2001, the average daily commute of these slum residents was 2.5 hours and consumed 15% of their daily wages. In response to these acute problems, in 1999 an innovative land-banking/poverty-alleviation program, called Metrovivienda, was introduced to provide affordable housing within an accessible distance from transit stations (Cervero, 2011). To achieve this, Metrovivanda officials who are also members of BRT planning bodies acquire the open land well in advance of transit operations at 'before transit' prices. Acquiring land for cheaper rates enables the Bogota officials to keep prices affordable for the people moving from peripheral slum areas.

All the aforementioned cities are successfully integrating affordable housing with affordable transit, due to the government, housing, and transit agencies interventions in TODs. However, in India, government interventions in the new developments around Metro appear to be slim due to lack of ownership of land and stringent inclusive policies.

This paper seeks to provide some quantitative assessment of the Indian TOD gentrification situation. According to the National Housing and Habitat policy, India is facing a shortage of 24.7 million HH units, and 99% of this shortage pertains to the economically weaker section (EWS) and low income group (LIG)(Ministry of Housing and Urban Poverty Alleviation, 2007). These numbers are increasing further due to rapid urbanization. Bengaluru is also facing many rapid urbanization issues especially after the IT boom since 1990s. To address these issues, the city is embracing transit and TODs. However, despite policies the extent of new developments incorporating affordable housing is not clear. The current study seeks to answer the question in the context of Bengaluru: can a more sustainable transit policy also include equitable TODs?

To introduce the analysis, studies focused on gentrification issues in TODs and the indicators adopted to identify the gentrification are reviewed.

Gentrification in TODs and the Indicators Adopted to Identify Gentrification

Examination of housing inequities in new station area planning and associated gentrification has received relatively little attention in India, as gentrification has only recently become an emerging issue there. Some developed city studies can provide the kind of indicators needed to help quantify the situation in India.

Kahn, (2007) considered change in average home prices, the share of the college graduates and length of time for which census tracts (CT) were exposed to transit as indicators to gentrification. The study results indicate that, the walk and ride transit stations are undergoing through greater gentrification than the park and ride transit station. Feinstein and Allen, (2008) considered education, income, HHs receiving public assistance and in migration rate are the proxy measures of gentrification. Analysis of the results shows that, the extension of rail lines compels less affluent long established residents in rental housing to move due to increases in housing costs. Grube-cavers and Patterson, (2015) considered education, income, house rent, occupation, and the percentage of owner occupied houses are proxies to gentrification. The study concluded that, rail transit has had a significant impact on gentrification.

All the aforementioned studies focused on change in TOD socioeconomic characteristics over a period of time and compared it across neighbourhoods/cities. They identified the neighbourhoods with significant change, as going through gentrification. For many TOD neighbourhoods, the change is significant. Based on these findings, research often takes this change to be resulting from classic gentrification. However, none of these studies has documented how the neighbourhood's socioeconomic characteristics improved compared to the rest of the city, the process that drove the improvement (influx of gentrifiers/influx of new residential developments/improved status of existing residents) and what the consequences were (direct or exclusionary displacement, or no displacement). Moreover, the results from existing studies may not be directly applicable to cities in India or other developing countries. In such cities, large socio-economic disparities exist, but spatial disparities in income are less obvious because of the coexistence of the rich and the poor due to a combination of cultural and economic factors (Walker, 2013). Hence, it is not

clear if transit and associated new TODs have a gentrification effect on Indian station areas, like in some cities in developed countries. If a gentrification effect is triggered, what is its form and what are the consequences? This study addresses these queries in the context of Bengaluru by adopting gentrification indicators from the above studies.

To identify the gentrification in the new and old build developments in the case study area, the study adopts most of the gentrification indicators incorporated in the above studies, except two that are not applicable in this context. These two are: from Kahn's (2007) study, the length of time for which census tract (CT) were exposed to transit; from Feinstein and Allen's study (2008), the in migration rate. These indicators are meant for macro/city level analysis and are applicable only when comparing a neighbourhood with others. They will not be applicable for single neighbourhood analysis (micro level analysis). In addition to these indicators, the study includes housing affordability index (ration of housing price to income), rent burden (rent/income), length of the stay, age of the building and size of the house. The first two indicators help understand the spending patterns on housing. The third indicator provides data on when the residents moved to the study area relative to the transit investment. The last two indicators provide data on the condition of housing. Once the indicators were finalized, data on housing and socioeconomic characteristics were collected, as summarized below.

Data collection

In order to assess the newly constructed high rise housing prices in TODs and their affordability to various income groups in Bengaluru, the data on housing projects by location are required. However, Indian cities do not have an official record of data related to the housing supply and their characteristics. Therefore, the multi-unit housing projects/condominiums data as shown in Figure 1 were collected from the private organizations such as LJ Hookers and CREDAI Bengaluru. The condominiums database includes all the condominiums initiated in a five-year period (2009-2014), 2009 being the year the high density TOD policy was introduced in Bengaluru. The data include project status, number of units in each project, unit sizes, location, and market value. This housing data does not include informal or single family housing units.

Given that the density bonus is limited to 500 m from station areas, the new high rise houses located within this distance are referred to as 'new build TOD housing'. Apart from the housing statistics, to assess the association of gentrification with TOD housing, a case study (Yeshwanthpur Industrial area) was conducted located in middle suburbs. The metro has been operational here since 2013. The case study area comprised of old build traditional residential area on one side of the metro station and a new build high rise area (constructed on the brownfield abandoned land area) on the other (Figure 3). The case study area is ideal to demonstrate both the new build and old build gentrification.

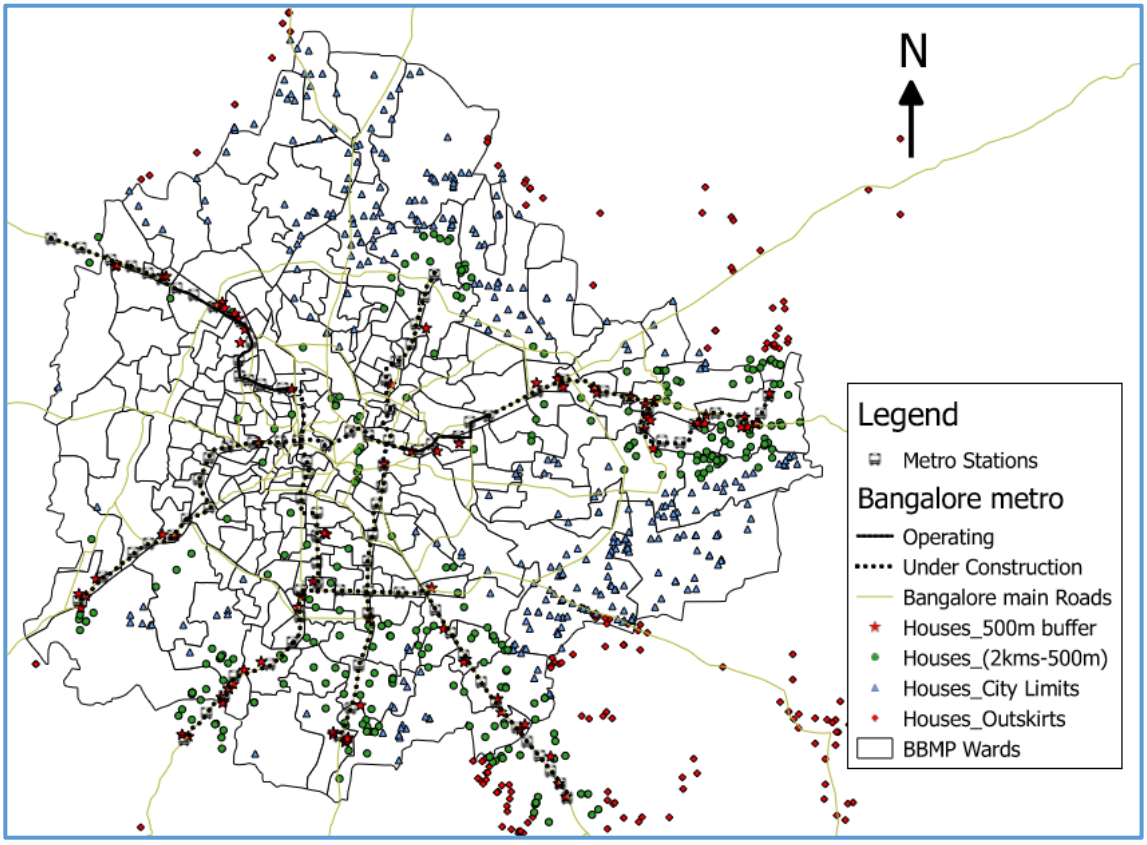

Figure 1: Condominium developments and their location in Bengaluru

In the case study area, due to lack of availability of pre-existing data on the socioeconomic characteristics of the residents, to identify gentrification, a primary HH survey was conducted. The case study area boundaries are defined within a half mile (~800 m) radius of transit stations (Center for Transit Oriented Development, 2007; Dominie, 2012; Guerra et al., 2011). To yield the best results a sample size of 10% of the population was selected for a population size of less than 50,000 (Bruton, 1985). To get the sample

representation from the new build and the old build TOD housing, stratified random sampling technique has adopted. The study area was classified into two strata: first stratum represents the old build TOD housing with around 3000 HHs; second stratum represents new build TOD housing with around 1000 HHs. With the 10% sample size, 400 HH surveys were conducted. Further, to assess the case study area's vulnerability for future gentrification, the land use data before and after construction of new build TOD housing and the data on proposed new housing projects, were collected.

Empirical Analysis

Assessment of new build TOD Housing Price and its Affordability

To assess the income groups being excluded from new build TOD housing, new TODs housing price and its affordability to various income groups was analyzed and compared with that of the rest of the city. The affordability of housing depends on the unit size, selling price per square meter and the income levels of the occupier (Jones Lang Lasalle, 2012). Though the selling price is high, if the unit size is small, the total price of the housing unit can be reduced (Renne, 2014). Hence, prior to assessing the housing units' affordability, the study looks at whether there is any such situation in the Bengaluru context by analyzing the unit size and per square meter price as well.

To analyze the variations in selling price and housing unit size across the city, the city was classified into four parts depending on distance from the transit stations (Table 1). The results indicate that, new build TOD housing is 68% higher than that of the housing located in peripheral areas. It might be due to various heterogeneous factors such as transit, zoning incentives, major roads, neighborhood land use and design. However, the study is not focusing on these factors. It is mainly focusing on new TODs housing price and its affordability to various income groups. Housing located within 500 m to 2 km from the transit station is 51% higher in price. However, the locational advantage of being generally in the city rather than outside city limits is such that in the non-TOD area there is still a 41% higher value than in suburbs located outside the city limits.

Table 1: Size and average selling price of condominiums, by location.

Location	Cost in INR /sq. Meter	1 BHK*	2 BHK	>2 BHK
Within 500 Meters (% of to outside city limits)	62000 (68%)	3%	42%	55%
500 Meters to 2 KM (% of to outside city limits)	56000 (51%)	3%	36%	61%
2 KM to city limits (% of to outside city limits)	52000 (41%)	8%	34%	58%
Outside city limits	37000	8%	39%	53%

On the other hand, the housing composition in Table 1 indicates that irrespective of location, more than 90% of new build TOD housing has a minimum two or more bedrooms, hall and kitchen (2 BHK); only a small fraction of housing units have one bedroom, hall and kitchen (1BHK). The housing projects located within 2 km from the transit station showed an even further reduced supply of small housing units. However, according to the Ministry of Housing & Urban Poverty Alleviation, a 1BHK house, for which the size is generally less than 600 sq. feet, is referred to as affordable to the economically weaker section and for low income groups. These data demonstrate that overall the new build TOD housing opportunities for the poor are much fewer in the city, and even sparser around transit stations, due to the higher housing values and larger unit sizes. The single family, informal (slum) and smaller housing construction are likely to continue to be built across the city, including in TOD locations, but there is no available data on this. However, it appears that the construction of new build high density housing is excluding some income groups, especially near transit stations, i.e across Bengaluru there is substantial new build gentrification occurring.

To understand further which income groups are excluded from new build TOD housing, the locational housing project prices are compared and the income groups who can afford to own those projects are also mapped. To assess the housing affordability of people based on their income, the HAI of various income groups are drawn from the literature. In the academic literature, the index is defined in two ways. One is the proportion of gross income spent towards either equated monthly installment (EMI) or rent, and the other is the ratio of the total house price and the gross annual HH income (Kosareva and Tumanov,

2008; Neill et al., 2008). Due to lack of available data on rental values, in the current study HAI is defined in terms of the ratio of housing price to annual gross HH income. In the literature the index varies from country to country, and ranges from 3 to 16 (Kosareva and Tumanov, 2008). In India HAI is based on the income group. For an income group from INR 100,000 to 300,000 (referred to as EWS and LIG) the index should not exceed 3. For income groups above INR 300,000 it should not exceed 4 (MHUPA 2008; MHUPA 2011). Depending upon the affordability Index and market price of housing provided by LJ Hookers, the income groups who can afford to own new build TOD housing are highlighted and compared with the rest of the city in Figure 2.

The locational housing price analysis indicates that the minimum price of new build TOD housing units starts from INR 2.5 million, and most of these units fall within the price range of INR 5 to 7.5 million.

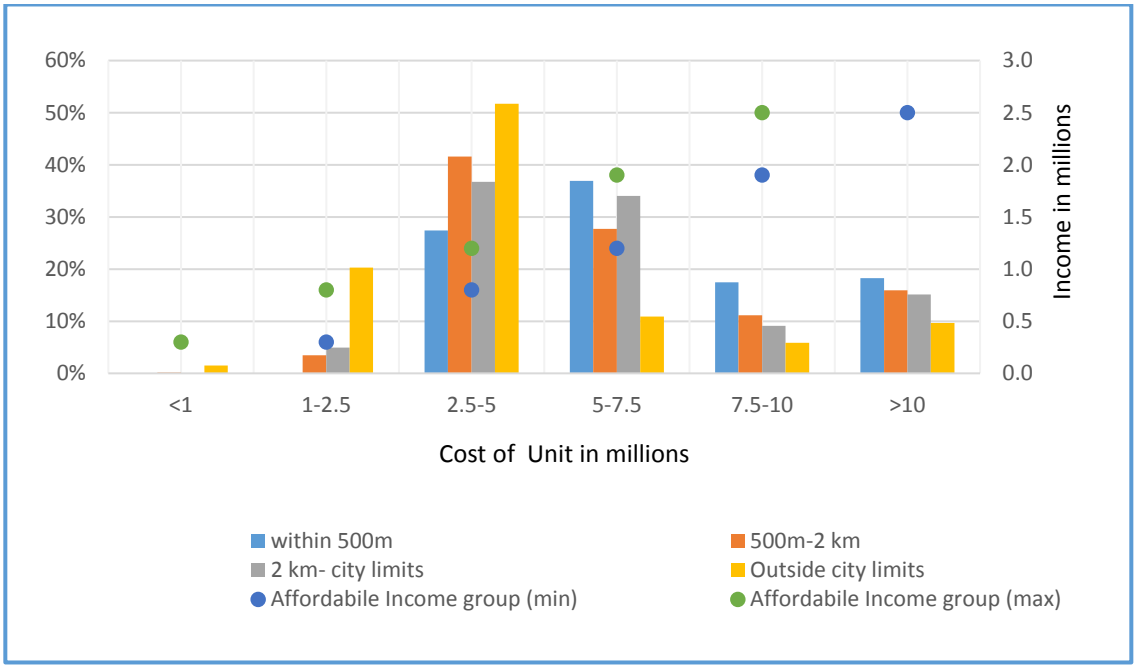

Figure 2: Condominium price comparisons in INR and mapping of affordable income groups to own a house, by location.

The mapping of income groups who can own housing units indicates that, to own a house close to transit, the minimum income level should be 0.6 million per annum (by assuming the affordability index of 4). It is much higher than the average annual income levels in Bengaluru, which is around INR 0.15 million (RITES, 2011). It also indicates that, for

low income groups the preferred locations are suburbs. Even for INR 0.6 million income the percentage of housing options close to transit is low (around 25%) compared to that for high income groups (around 75%).

In summary, the prevailing housing prices and analysis of their affordability indicate that, because of the high prices and large unit size, the new build high density housing, especially in TODs, are unaffordable for the poor. As a consequence of excluding the poor and attracting the rich, the TODs may undergo new build gentrification. It may also change the whole nature of the TOD area and consequently new build gentrification may trigger the old build gentrification of traditional areas (Davidson and Lees, 2005). To test this hypothesis, a case study has been undertaken to understand the contribution of new build TOD housing to change in the socioeconomic characteristics of the new and old build TOD area.

Yeshwanthpur Industrial area: A Case study

To assess the impact of the unaffordability of new build TOD housing on neighborhood gentrification in Bengaluru, the Yeshwanthpur industrial area was selected for a case study. Metro started operating in the study area in 2013. Historically, the study area is a working class neighborhood and once had an important industrial hub of the city. It comprised of old build residential area on one side of the metro station; and industrial, vacant and brownfield land on the other. Lately, the side of the industrial, vacant and brownfield land has witnessed high rise newly built TODs. Up to 2014, these condominiums have added around 1000 HHs in this area. Two high rise structures were under construction in 2015 and many more are under planning review and potentially to be built in response to availability of land, as illustrated in Figure 3.

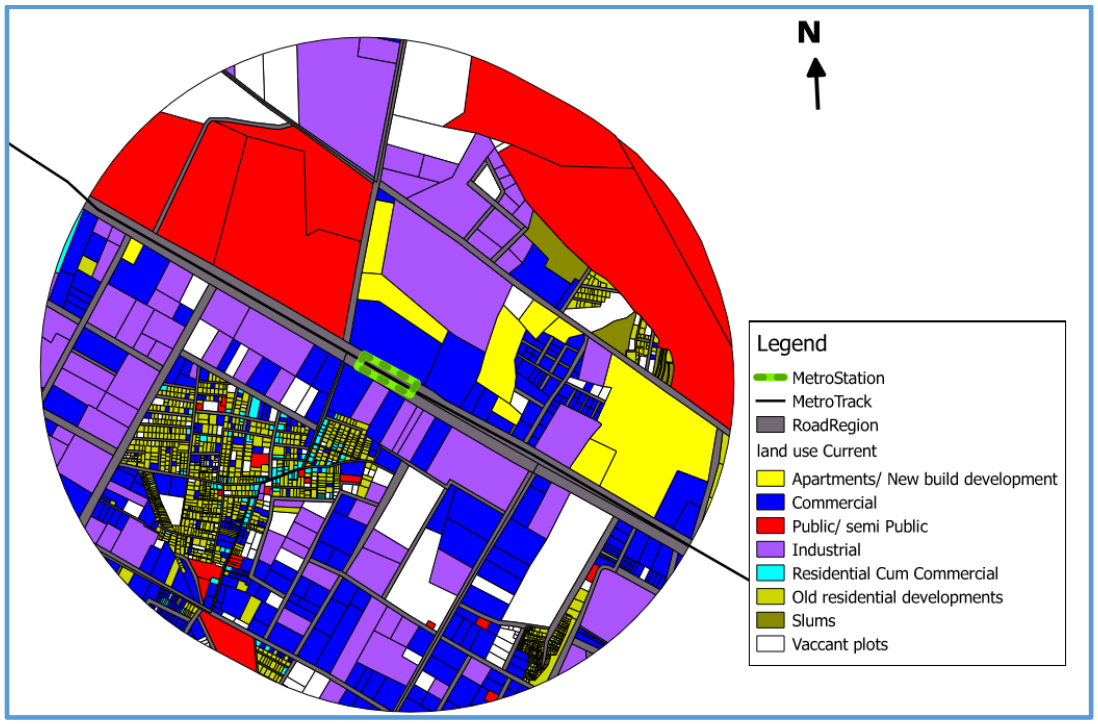

Figure 3 : Case study area boundaries and land use characteristics.

All the new build TOD housing are concentrated on one side of the road and clearly segregated from the old build area, which consists of traditional high density, low rise developments in typical Bengaluru style walk-up developments of three to four stories. In the old residential area there are no new high rise redevelopments like those on the other side of the Metro because due to small plot sizes and difficulties in the amalgamation of land. However, these public and private investments in the neighborhood, may attract the gentrifiers in the old residential area and can create an old build gentrification.

The new condominiums on the other side of tracks that have already been occupied are luxurious, with swimming pools, fitness centers and clubhouses. On an average, the housing in these condominiums costs INR 60,000 per sq.m, approximately equal to the average price of new build TOD housing as highlighted in Table 1. In addition, the rents in these condominiums are much higher than in the local residential area. They are also higher than the average monthly income of Bengaluru residents, which is around INR 11,500 (RITES, 2011). The variation in rental values clearly reflects the variation in economic characteristics of old and new residential areas. To explore whether the

neigbourhood is undergoing any new or old build gentrification , the socioeconomic characteristics of the neighborhood are analysed.

Gentrification identification

In order to identify new and old build gentrification, the socio-economic indicators drawn from the literature section are adopted. Based on HH survey data, gentrification indicators of the old and new residential area are evaluated. In the existing literature on identifying gentrification in a neighbourhood, the change in socioeconomic indicators is analysed for a said time period, and compared with the rest of the city. This methodology helps identify gentrification, but not its particular form (new build or old build gentrification). Further, this methodology requires the socioeconomic characteristics' data (over a period) for the whole city. Such data is not readily available in developing countries like India, compelling studies to rely on expensive and cumbersome HH surveys. In such situations, a more suitable approach is that of comparative analysis, also adopted in this study. To determine whether the new developments are attracting only gentrifiers or including all income groups, as traditional Indian neighbourhoods do, the study compares the socioeconomic indicators of new and old build residents. To check for any influx of gentrifiers in the old residential area, the socioeconomic indicators of recently-moved neighbours (less than 5 years) are compared with those of the residents staying for several years. The comparative analysis yields a statistically significant difference in the indicators, leading us to conclude that transit neighbourhoods are triggering gentrification. The approach is more suitable to the developing countries where the change in socioeconomic characteristics cannot be analyzed over a period of time due to lack of data.

New Build gentrification

Table 2 : Socioeconomic and housing characteristics of old and new build TODs residents.

Indicator	Old Build TOD housing		New Build TOD housing		Sig.
	Mean	Variance	Mean	Variance	
1. Home price (Lakhs INR)	81	13245	90	626	0.19
2. Rents (INR)	3307	2118977	29153	16141026	<0.01
3. Rent burden	16%	84	28%	53	<0.01
4. HAI	35	2782	7.9	7	<0.01
5. House area (Sq.ft)	650	132130	1594	75556	<0.01
6. Household size	2.97	1.23	3.04	1.2	0.34
7. Building age	19	279.	3.9	1.77	<0.01
8. Time of the stay	18	346.52	2.2	1.44	<0.01
9. Tenure arrangement	Own = 31 % Rent = 61%Lease = 8 %		Own = 56 % Rent = 44%		NA
10. Vehicle ownership	Two wheeler = 0.3 Car = 0.05		Two wheeler = 0.34 Car = 1.11		NA
11. Age distribution	<18 = 23 **%** 18-40 = 51 **%** 40-65 = 24 **%** >65 = 2 **%**		<18 = 19 **%** 18-40 = 49 **%** 40-65 = 28 **%** >65 = 4 **%**		NA
12. HH's receiving government assistance	64 %		0		NA
13. Annual Income Diversity	< INR 150 k = 18 % INR 150 - 300 k = 52 % INR 300 - 500 k = 24 % INR 500 -1000 k = 6 %		INR 300 - 500 k = 23 % INR 500 - 1000 k = 5 % > INR 1000K = 75 %		NA
14. Employed resident's occupation	Working class = 44 % Self-employed = 23 % Professional = 24 % Retired = 3 % Unemployed = 6%		Working class = 0 % Self -employed = 19 % Professional = 65 % Retired = 16 % Unemployed = 0 %		NA
15. Educational levels of adults	Illiterates = 17% Below 12th class = 56 % Graduation = 25 % Post-Graduation = 2 %		Illiterates = < 1 % Below 12th class = < 1 % Graduation = 61 % Post-Graduation = 37 %		NA

As shown in Table 2, apart from HH size housing price and age distribution, the difference between the old and new residential areas are quite evident with a statistical significance of less than 0.01. The new being significantly wealthier, more professional, better educated and owning an average one car per family. Though the difference between the average housing price of new and old developments is not significant, the variance of housing price in the old residential area is high, indicating the availability of different houses in different price ranges. This reflects that unlike the new residential area, the old residential area is mixed income in nature, offering housing options for low to high income groups.

Although otherwise suggested by the existing literature in developed countries (Litman, 2013, Neill et al., 2008), the percentage of monthly income spending on house rent is found to be high among wealthier, new residential area residents than that of the old development area residents. However, the housing affordability index of the old residential area is very high compared to that of the new residential area. This is attributable to the fact that most of the properties in the old residential area are ancestral in nature, with the average building age of 19 years, and free of any EMI liability for the current residents.

Old Build gentrification

Table 3: Socioeconomic and housing characteristics of newly moved residents and the residents staying from long back in old residential area.

Indicator	1-5		>5		Sig.
	Mean	Variance	Mean	Variance	
1. Home price (Lakhs INR)	56	12902	86	13384	>0.05
2. Rents (INR)	3050	1717446	3478	2263426	>0.05
3. Rent burden	16	86	16	85	>0.05
4. HAI	24	806	37	3226	>0.05
5. House area (Sq.ft)	695	133589	651	128860	>0.05
6. Building age	10	173	22	286	>0.05
7. Tenure arrangement	Own = 53 % Rent = 44% Lease = 3 %		Own = 19 % Rent = 76% Lease = 5 %		NA
8. Vehicle ownership	Two wheeler = 0.27 Car = 0.04		Two wheeler = 0.38 Car = 0.05		NA
9. Age distribution	<18 = 22 % 18-40 = 60 % 40-65 = 17 % >65 = 1%		<18 = 22% 18-40 = 49 % 40-65 = 26 % >65 = 3 %		NA
10. HH's receiving government assistance	67%		70%		NA
11. Annual Income Diversity	< INR 150 k = 20 % INR 150 - 300 k = 58 % INR 300 - 500 k = 16 % INR 500 - 1000 k = 6 %		< INR 150 k = 17 % INR 150 - 300 k = 49 % INR 300 - 500 k = 25 % INR 500 - 1000 k = 9 %		NA
12. Employed resident's occupation	Working class = 58 % Self-employed = 12 % Professional = 27% Unemployed = 3%		Working class = 38 % Self-employed = 27 % Professional = 24 % Retired = 4 % Unemployed = 6%		NA
13. Educational levels of adults	Illiterates = 12 % Below 12th class = 62 % Graduation = 25 % Post-Graduation = 1 %		Illiterates = 18 % Below 12th class = 54 % Graduation = 24 % Post-Graduation = 3 %		NA

As shown in Table 3, there is no statistically significant difference between the socioeconomic characteristics of the residents who moved in recently and those staying for long, which reflects that the recently moved neighbours are not gentrifiers, rather class people like the existing residents.

From these findings, there is little doubt that the new build TOD housing is creating new build gentrification, however, they are not creating old build gentrification in the old build TOD area. The traditional area income distribution and vehicle ownership rates are roughly same as for the Bengaluru (RITES, 2011). Though, according to various studies, the influx of wealthy residents contributes to transit ridership and reduces traffic congestion (due to shifting from private vehicles to transit), generates jobs for the poor and improves the local economy (Meltzer, R., Schuetz, 2012; Schuetz et al., 2012). Yet the trend of encouraging only the influx of wealthier residents in the new developments eventually shuts out those with low income from these TOD areas, and the poor will lose a chance to utilize the affordable public transit, unless housing authorities and transit agencies step in to include affordable and small size housing in these new build developments. It is also essential to maintain the old residential area if social exclusion in TOD areas is not to be encouraged. To better understand the influence of important economic indicators on choosing new build TOD housing, a sensitivity model is developed.

Assessing Influence of socioeconomic characteristics on choosing new build TOD housing. In order to quantify the sensitivity of choosing new build TOD housing to income, occupation and education, a predictive model is developed. In the model, income is classified majorly into three groups and coded as: 1- for income group less than INR 0.5 million; 2- for income group less than INR 1 million; 3- for income group more than INR 1million. Occupation and education attainment is considered in terms of the number of professional employees per HH and number of college graduates per HH. Once the variables are determined, as illustrated in Figure 4, the probability is plotted of choosing new build TOD housing with respect to each variable when the rest of the variables remain constant.

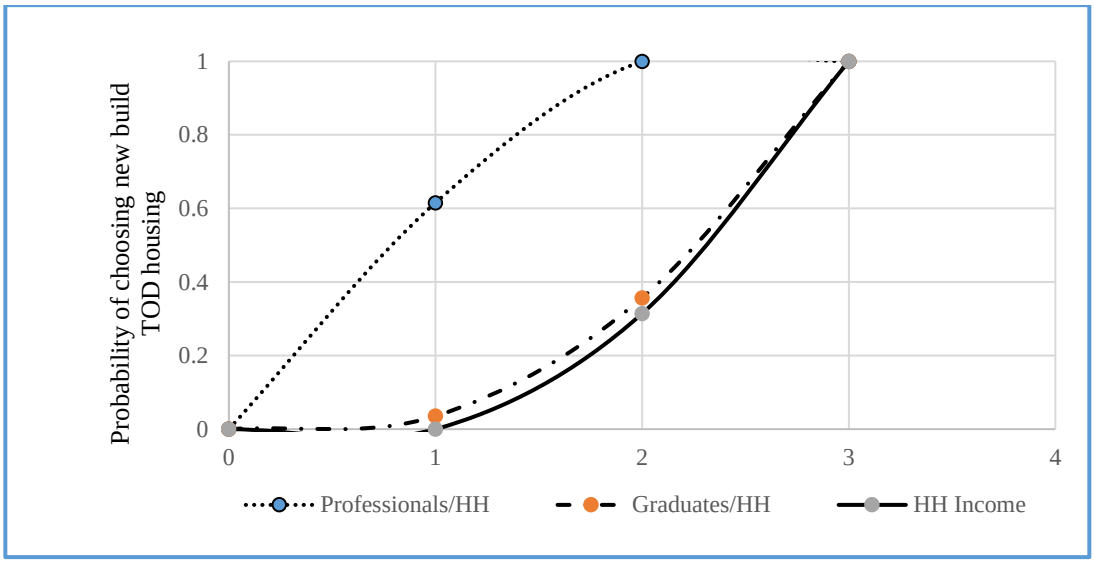

Figure 4 : Sensitivity of choosing new build TOD housing to income, education and occupation.

The model shows a clear correlation between choosing new build TOD housing with occupation, income and education. The probability of choosing new build TOD housing increases continuously with number of professionals per HH followed by graduates per HH and income. It indicates that all the graduates are not in high paid professional jobs and the professional employees are earning more than the HH income threshold levels provided on X- axis. Overall the analysis reflects that, as the HH socioeconomic characteristics improves, the probability to opt for new build TOD housing increases. The model suggests that, to reduce the social exclusion in these rapidly gentrifying areas, more affordable housing options will be needed. If not, the neighborhood will undergo further gentrification**.** To explore this challenge, the neighborhood susceptibility to future gentrification in case of a 'do nothing' scenario is assessed**.**

Predicting Susceptibility to further gentrification

The difference in socioeconomic indicators in the new build TOD housing compared to the old traditional area on the other side of the station indicates how rapidly gentrification is happening. To assess the susceptibility to future new build gentrification, the study analyzed the characteristics of condominiums under construction and their affordability. Further, the land availability for future high rise developments are assessed through change in land use analysis before and after new build TOD developments.

Currently in the study area, there are two high rise condominiums which are under construction. The two apartment complexes are adding another 600 units to the neighborhood, which are spread over around 10 acres of land. These two condominiums are far more luxurious than the existing condominiums. The price of the housing units in these projects vary from INR 25 to 136 million. The cost of these condominiums under construction clearly indicates that, to own a house here, the minimum income of the occupants should be at least INR 6 million per annum. This reflects a significant further social exclusion of many income groups from occupying the new build TOD housing.

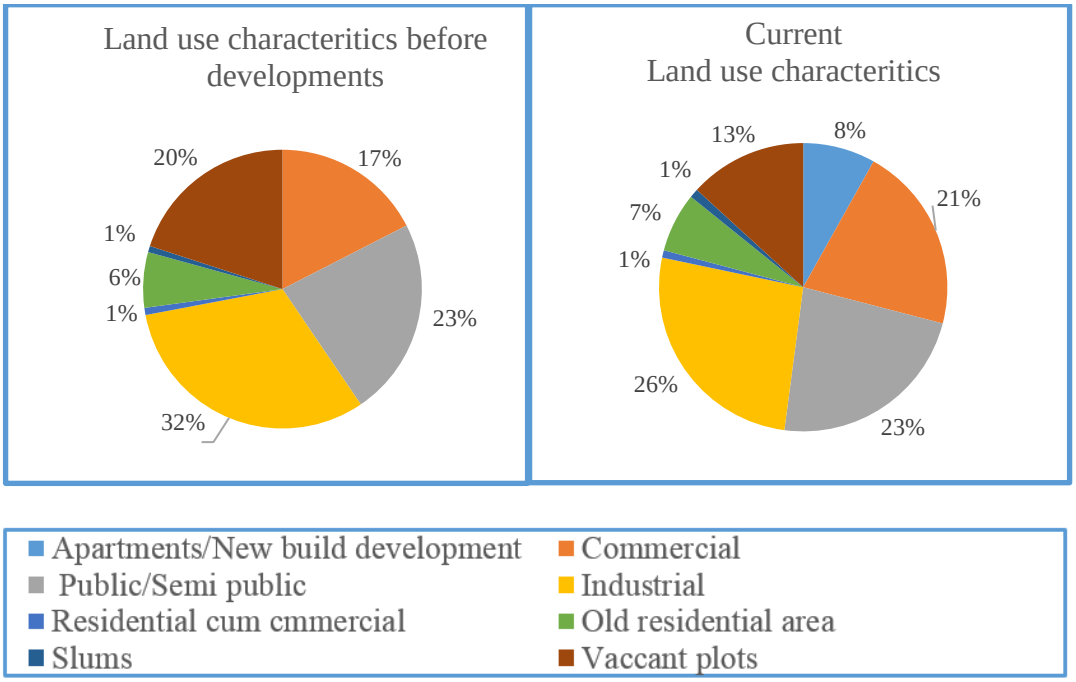

Figure 5: Change in land use characteristics due to new build development.

On the other hand, the land use analysis prior to and after new build TOD housing indicates that, the existing new build TODs are majorly occupying the vacant and industrial areas. Hence, the proportion of these lands are slowly reducing while the proportion of commercial and high-end residential structures are increasing (Figure 5). In addition, the land use analysis clearly indicates that there is still a huge scope for further new TODs in the study area, due to the availability of large parcels of vacant and industrial area. However, there are no apparent plans to remove or redevelop the old residential area, which offers substantial PT benefits to its residents, now that they live adjacent to the

metro. This traditional area needs to have careful policy engagement to enable its mix of building types and incomes to continue (Feinstein and Allen, 2008).

Conclusion

Indian cities, like many across the world, are undergoing a rapid transformation including the development of metros and associated TODs. Due to such huge public infrastructure investments the potential for new build and old build gentrification is very high and the data gathered for Bengaluru suggests that the new build TOD housing is indeed leading to new build gentrification. A detailed case study analysis based on a HH survey confirms this. However, the data also show that new build gentrification has not yet impacted on the old build traditional area housing on the other side of the station area. Thus old build gentrification of the traditional kind found in the US and Europe has not yet happened. This may change once the vacant area land in the new build area has been built out.

The need to begin introducing policies to reduce gentrification in new build and old build areas should now be under consideration as most metros in Indian cities are only just beginning to be built.

New build policies should include:

1. Ensuring a higher proportion of small size units in all new build TOD housing

2. Providing inclusionary housing incentives (density bonuses, minimum parking, tax exemptions, and affordable housing grants).

Old build policies should include:

1. Maintaining small lot policies
2. Purchasing low value houses and redeveloping them for poorer residents

Without these policies housing development authorities will continue to choose peripheral areas to develop affordable housing to reduce production costs. The residents of these developments, however, often lose their livelihood because they have to locate away from urban opportunities. According to Litman, “housing is not really affordable if located in isolated areas with high transportation costs. True affordability therefore requires affordable-accessible housing” (2013, pg no: 7). To enable this transit and housing,

authorities must come up with innovative strategies and financial tools for inclusive TODs.

References:

Atkinson R (2000) Measuring Gentrification and Displacement in Greater London. Urban Studies, 37(1), 149–165.

Bangalore Metropolitan Rail Corporation Limited (2016) Available from: www.bmrc.co.in.

Bruton MJ (1985) Introduction to transportation planning. Hutchinson, London.

Center for Transit-Oriented Development (2009) Mixed-Income Housing Near Transit: Increasing Affordability With Location Efficiency. Washington D.C, Available from: tod-201-mixed-income-housing-near-transit-increasing-affordability-with-location-efficiency.

Cervero R (1994) Transit-based housing in California: evidence on ridership impacts. Transport Policy, 1(3), 174–183, Available from: http://linkinghub.elsevier.com/retrieve/pii/0967070X94900132.

Cervero R (2010) Transit Transformations: Private Financing and Sustainable Urbanism in Hong Kong and Tokyo. In: Ascher W and Krupp C (eds), Physical Infrastructure Development: Balancing the Growth, Equity and Environmental Imperatives, New York: Palgrave Macmillan, pp. 165–185.

Cervero R (2011) State Roles in Providing Affordable Mass Transport Services for Low - Income Residents. In: International Transportation Forum, 25- 27 May, Leipzig, Germany.

Cervero R and Kockelman K (1997) Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon, 2(3), 199–219.

Cervero R and Murakami J (2009) Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Studies, 46(10), 2019–2043.

Chava J, Newman P and Tiwari R (2016) Gentrification of station areas and its impact on transit ridership. Curtin University, Perth, WA.

Davidson M (2007) Gentrification as global habitat: a process of class formation or corporate creation? Transactions of the Institute of British Geographers, 32(4), 490–506, Available from: http://doi.wiley.com/10.1111/j.1475-5661.2007.00269.x.

Davidson M and Lees L (2005) New-build gentrification and London's riverside renaissance. Environment and Planning A, 37, 1165–1190.

Dominie W (2012) Is Just Growth Smarter Growth ? The effect of Gentrification on Transit Ridership and Driving in Los Angele's transit station area Neighborhood. University of California, Berkley.

Dziauddin MF (2009) Measuring the Effects of the Light Rail Transit System on House Price in the Klang Valley, Malaysia. Thesis (PhD), Newcastle University.

Ellen IG and O'Regan KM (2011) How low income neighborhoods change: Entry, exit, and enhancement. Regional Science and Urban Economics, 41(2), 89–97.

Fan Y and Guthrie A (2012) Winners or Losers. Transportation Research Record: Journal of the Transportation Research Board, 2276, 89–100, Available from: http://trb.metapress.com/openurl.asp?genre=article&id=doi:10.3141/2276-11 (accessed 11 April 2014).

Feinstein BD and Allen A (2008) Article Community Benefits Agreements with Transit Agencies : Neighborhood Change Along Boston's Rail Lines and a Legal Strategy for Addressing Gentrification. Transportation law Journal, 38(85), 85–114.

Freeman L and Braconi F (2004) Gentrification and Displacement. Journal of the American Planning Association, 70(1), 39–52.

Ghertner DA (2014) India's urban revolution: geographies of displacement beyond gentrification. Environment and Planning A, 46(7), 1554–1571, Available from: http://epn.sagepub.com/lookup/doi/10.1068/a46288 (accessed 11 May 2016).

Glass R (1964) Introduction: Aspects of Change. In: London : MacGibbon & Kee: Macgibbon & Kee.

Government of Karnataka (2009) Amendment to the zoning regulations of master plan of Bangalore. UDD 93 MNJ 2008, India.

Grube-cavers A and Patterson Z (2015) Urban Rapid Rail Transit and Gentrification in Canadian Urban Centres – A Survival Analysis Approach. Urban studies, 50(1), Available from: https://www.cirrelt.ca/DocumentsTravail/CIRRELT-2013-06.pdf.

Guerra E, Cervero R and Tischler D (2011) The Half-Mile Circle: Does It Best Represent Transit Station Catchments? Report, Institute of Transportation Studies, University of California, Berkeley.

Hackworth J and Smith N (2001) The changing state of gentrification. Tijdschrift voor Economische en Sociale Geografie, 92(4), 464–477, Available from: http://doi.wiley.com/10.1111/1467-9663.00172.

He S (2010) New-Build Gentrification in Central Shanghai: Demographic Changes and Socioeconomic Implications. Population, Space and Place, 361(July 2009), 345–361.

Jones Lang Lasalle (2012) Affordable Housing in India: An Inclusive Approch to Sheltering the Bottom of the Pyramid. Report, New Delhi.

Kahn ME (2007) Gentrification Trends in New Transit-Oriented Communities : Evidence from 14 Cities That Expanded and Built Rail Transit Systems. Real Estate Economics, 35, 155–182.

Knaap GJ, Ding C and Hopkins LD (2001) Do Plans Matter?: The Effects of Light Rail Plans on Land Values in Station Areas. Journal of Planning Education and Research, 21(1), 32–39, Available from: http://jpe.sagepub.com/cgi/doi/10.1177/0739456X0102100103 (accessed 27 May 2014).

Kosareva N and Tumanov a. (2008) Assessing Housing Affordability in Russia. Problems of Economic Transition, 50(10), 6–29, Available from:

http://mesharpe.metapress.com/openurl.asp?genre=article&id=doi:10.2753/PET1061-1991501001 (accessed 5 May 2014).

Land M Van Der, Curley A and Eijk G Van (2012) Gentrification and Neighbourhood Change. In: International Encyclopedia of Housing and Home, Elsevierr Ltd., pp. 275–279, Available from: http://dx.doi.org/10.1016/B978-0-08-047163-1.00594-4.

Lees L, Slater T and Wyly EG (2008) Gentrification. Routledge, New York: New York: Routledge.

Lin J (2002) Gentrification and Transit in Northwest Chicago. Journal of Transport Research Forum, 56(4), 175–191.

Litman T (2005) Impact of Rail Transit on the Performance of a Transport System. Transportation Research Record 1930, Transportation Research Board, 23–29.

Litman T (2013) Affordable-Accessible Housing In A Dynamic City Why and How To Increase Affordable Housing Development In Accessible Locations. Report, Victoria Transport Policy Institute, Canada.

McIntosh J, Turbka R and Newman P (2013) Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. Transportation Research - Part A, 67, 320–339.

Meltzer, R., Schuetz J (2012) Bodegas or Bagel Shops? Neighborhood Differences in Retail & Household Services. Economic Development Quarterly 26: 0891242411430328.

Ministry of Housing and Urban Poverty Allevation (2009) Guidelines for affordable housing in partnership. Government of India, New Delhi.

Ministry of Housing and Urban Poverty Allevation (2013) Affordable housing in partnership Scheme guidelines. Government of India, New Delhi, Available from: http://mhupa.gov.in/W_new/AHP_23_09_2013.pdf.

Ministry of Housing and Urban Poverty Alleviation (2007) National Urban Housing and Habitat Policy. Report, Government of India, New Delhi, Available from: http://mhupa.gov.in/policies/duepa/HousingPolicy2007.pdf.

Murphy L (2008) Third-wave Gentrification in New Zealand: The Case of Auckland. Urban Studies, 45(12), 2521–2540, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097106 (accessed 11 May 2016).

Neill PO, Johnston K, Phibbs P, et al. (2008) Housing Affordability Literature Review and Affordable Housing Program Audit. Urban Research Center, University of Western Sydney, Sydney, Available from: www.uws.edu.au/__data/assets/pdf_file/0004/164623/landom_report_2008-07-21.pdf.

Newman P and Kenworthy J (2015) The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning. Washington D.C: Island Press.

Newman P and Matan A (2013) Green Urbanisam in Asia: The Emerging Green Tigers. Ying LX (ed.), World Scientific.

Planning Commission (2013) Recommendations of Working Group on Urban Transport for 12th Five Year Plan. New Delhi.

Reconnecting America, Center for Community Innovation and Non-Profit Housing Association of Northern California (2007) Transit-Oriented for All : The Case for Mixed-Income Transit-Oriented Communities in the Bay Area. Berkeley, CA: Center for Community Innovation, Available from: http://communityinnovation.berkeley.edu/Publications.

Renne JL (2014) TOD Index TM. Report, University of New Orleans, Available from: www.TODindex.com.

Rérat P, Söderström O, Piguet E, et al. (2010) From Urban Wastelands to New-Build Gentrification : The Case of Swiss Cities. POPULATION, SPACE AND PLACE, 10(16), 429–442.

RITES (2011) Comprehensive Traffic & Transportation plan for Bengaluru. Report for Karnataka Urban Infrastructure Development and Finance Corporation, Bengaluru.

Schuetz J, Kolko J and Rachel M (2012) Are Poor Neighborhoods 'Retail Deserts'? Regional Science and Urban Economics, 42(1), 269–285.

Song W and Zhu X (2011) Gentrification in Urban China under Market Transformation. International Journal of Urban Sciences, 14(2), 152–163, Available from: http://www.tandfonline.com/doi/abs/10.1080/12265934.2010.9693673 (accessed 11 May 2016).

Tsietsi Monare P, Kotzé N and Morton McKay T (2014) A second wave of gentrification: The case of Parkhurst, Johannesburg, South Africa. Urbani izziv, 25(Supplement), S108–S121, Available from: http://urbani-izziv.uirs.si/Portals/uizziv/papers/urbani-izziv-en-2014-25-supplement-008.pdf (accessed 11 May 2016).

Van Gent WPC (2013) Neoliberalization, Housing Institutions and Variegated Gentrification: How the 'Third Wave' Broke in Amsterdam. International Journal of Urban and Regional Research, 37(2), 503–522, Available from: http://doi.wiley.com/10.1111/j.1468-2427.2012.01155.x (accessed 11 May 2016).

Visser G and Kotze N (2008) The State and New-build Gentrification in Central Cape Town, South Africa. Urban Studies, 45(12), 2565–2593, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097104 (accessed 31 March 2014).

Walker S (2013) The Handbook of Design for Sustainability. Illustrate. Walker S and Giard J (eds), A&C Black.

Zuk M, Bierbaum A, Chapple K, et al. (2015) Gentrification, Displacement, and the Role of Investment: A Literature Review. Federal Reserve Bank of San Francisco.

Manuscript 2: Gentrification of station areas and its impact on transit ridership

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Jyothi Chava, PhD Candidate

Newman, P: (Principle Supervisor) (10% Contribution)

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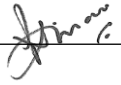
Supervised and assisted with manuscript compilation, editing and co-authorship of manuscript.



Professor Reena Tiwari, Co-Supervisor

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Gentrification of station areas and its impact on transit ridership

Abstract

Transit and transit-oriented developments (TODs) are gaining momentum across the globe to enable transport sustainability. However, most of these TODs are creating neighbourhood gentrification as a result of higher housing prices. Hence, the contribution of TOD policies towards equity as well as sustainable transportation goals remains unclear. This paper uses Bengaluru, India, as a case study to examine the effects of TOD gentrification on transit ridership. In Bengaluru, a high-density TOD policy has been introduced in the vicinity of station areas with the objective of increasing transit ridership. As a result, a new market for luxurious high-rise housing has emerged around suburban transit stations. These developments are expensive and accommodate professionals with a high income and high level of vehicle ownership, leading to neighbourhood gentrification. This study evaluates the impact of these newly built high-rise developments on transit ridership. Data analysis suggests that, irrespective of their economic status, gentrifiers contribute significantly towards metro ridership because of the metro's high level of service (LOS) in terms of comfort, convenience and saving travel time. In contrast, bus use among gentrifiers is less because of its low LOS. Although metro ridership among gentrifiers is high, to ensure equity there is a need to provide the same access benefits for others with less means. Hence, for more equitable and sustainable TODs this study recommends provision of affordable housing and mode integration policies along with a high-density policy.

1 Introduction

Improved transit accessibility and associated transit-oriented developments (TOD) are increasing housing cost in TODs (Newman and Kenworthy, 2015; Jillella et al., 2015). As high-income professionals are occupying most new build TODs, these are becoming susceptible to various forms of gentrification and equity issues (Lin, 2002; Kahn, 2007; Feinstein and Allen, 2008; Chapple, 2009; Grube-cavers and Patterson, 2015; Chava et al., 2016). Hence, to draft an equitable and sustainable TOD policy it is essential to understand the impact of this influx of wealthy residents on transit ridership and the

influence of well-planned transit on the travel pattern of gentrifiers. Surprisingly, these issues have attracted little attention of transport planners and equity advocates (Pollack et al., 2010). Two broad questions underlying this paper are:

1. Do TOD gentrifiers with a high income and vehicle ownership adhere to their unsustainable private modes or do they change their modes of transport and become transit riders like the economically weaker local residents? And,
2. How should transport planners include equity considerations in TOD projects?

The study explores these questions in one of the gentrifying working-class suburban metro station areas (Yeshwanthpur industrial area) in Bengaluru. The case study area is lately witnessing the construction of luxurious condominiums with the advantage of high-density policies and accessibility to the metro. The study examines the travel behaviour of old build TOD housing residents (non-gentrifiers) and residents of these new build luxurious condominiums (gentrifiers). To quantify the impact of gentrification on public transit (PT) ridership in TODs, a model was developed to predict the influence of key gentrification parameters on PT mode choice. In addition, the travel pattern of metro users before and after metro rail operations in the case study area were analysed to assess the influence of mass transit on TOD residents. Within the context of the two broad questions above, the study results therefore aim to answer the following detailed questions:

1. How does travel behaviour of gentrifiers differ from that of non-gentrifiers?
2. What is the influence of socioeconomic factors underlying gentrification on choosing PT?
3. What is the influence of mass transit on changing travel behaviour of TOD residents?

Section 2 is a literature review. Sections 3 and 4 present the research methodology and the empirical analysis, respectively. Finally, Section 5 discusses policy implications based on the results.

2 Literature review

This section presents an overview of gentrification, followed by the significance of the study and a review of studies specifically related to the impact of gentrification on travel behaviour.

2.1 An overview of gentrification

Gentrification refers to a process of displacement of low-income inhabitants by the influx of wealthy residents, leading to the social and economic upgrade of a working-class neighbourhood (Smith, 1982). Early gentrification literature focused primarily on the direct displacement of the poor from working-class neighbourhoods (Atkinson, 2000; Freeman and Braconi, 2004). However, over a period of time, gentrification has mutated and now extends to a form of 'exclusionary displacement' (Davidson and Lees, 2005; He, 2010). This form of gentrification is referred to as 'new build/contemporary gentrification' and is defined as 'the development of large, luxurious apartment complexes by corporate developers and their consumption by the professional middle classes' (Davidson, 2007, p. 493). These new-build developments often are on brownfield and vacant land and do not displace pre-existing residents in the same way as classic gentrification. However, these developments lead to social exclusion, indirect displacement of low-income residents and change in the social composition of the neighbourhood (Rérat et al., 2010a; Rérat et al., 2010b; Visser and Kotze, 2008).

The current study considers gentrification in the form of new-build gentrification due to developments of luxurious high-rise residential buildings in TODs. In the case study area, residents of these new high-rise developments are economically stronger than the working-class local residents (Chava et al., 2016a). Hence, in this study residents of these new luxurious condominiums, whose influx into the neighbourhood is leading to gentrification, are referred to as gentrifiers and residents already living/previously settled in the area are referred to as non-gentrifiers.

2.2 Why assess the impact of gentrification on transit ridership?

Across the globe implementation of various TOD policies is gaining momentum to achieve three common transportation objectives: (1) reduction in the number of motorized

trips, (2) increased share of non-motorized trips and (3) reduction of travel distances and the corresponding increase in vehicle occupancy levels of motorized trips (Cervero and Kockelman, 1997). The foremost aim of TOD policies is increasing densities around transit stations by allowing a high floor–area ratio (FAR), assuming that residents of these clustered developments will further increase transit ridership.

The high-density policy was introduced in Bengaluru with the same objective. As part of this policy, the FAR around metro stations/terminals increased to 4 for all permitted uses, irrespective of the applicable FAR (generally, it varies from 1.7 to 2.4 based on land use) (Government of Karnataka, 2009). Initially, the policy was limited to areas falling within the 150 m radius around transit stations; later, it was extended to a 500 m radius because of market pressure. As a consequence of this policy being associated with the real estate boom, most station areas are witnessing the development of high-rise structures, especially in the suburbs where larger vacant plots are available. However, as a result of a lack of affordable housing policies, most of these new clustered high-rise developments are expensive compared to non-TOD areas and unaffordable for most low- and middle-income groups. Consequently, station areas are going through new-build gentrification (Chava et al., 2016a), and the density policy contribution in achieving high transit ridership is not clear.

A few studies in developed countries establish the contribution of new clustered high-rise TODs towards increasing metro ridership (Cervero, 1993; Cervero, 1994; Lund et al., 2004; Lund, 2006; Cervero, 2007; Cervero, 2010; Mckibbin, 2011). However, no evidence shows that residents of high-rise developments are gentrifiers, like in Bengaluru.

Three reports and one published article (Danyluk and Ley, 2007; Kushto and Schofer, 2008; Pollack et al., 2010; Dominie, 2012) focus specifically on the influence of gentrification on travel behaviour in developed countries. These study results may not be applicable to the Indian context because of differences in built environment and large social, economic and behavioural disparities, which play a significant role in travel behaviour. In addition, none of these studies examine the influence of well-designed mass transit on the travel patterns of gentrifiers. The next section provides a summary of these

four studies to help understand the methodologies adopted and their applicability in the Indian context.

2.3 Gentrification and travel behaviour

Danyluk and Ley (2007) examined the relationship between gentrification and work-trip mode shares in three Canadian cities. This first study considers occupation and educational attainment as proxies for gentrification, and correlates them with work-trip mode shares at the census tract (CT) level. Their results conclude that, owing to liberal and political ideologies of gentrifiers, the residents of gentrified neighbourhoods are more likely to ride a bicycle to work and less likely to use PT compared to the residents of non-gentrified neighbourhoods. Unfortunately, the study omits several other important gentrification indicators such as income and vehicle ownership which have more influence on transit ridership (Cervero, 2007; Renne, 2003; Hendricks et al., 2005). In addition, the study does not control for built-environment parameters in a neighbourhood. This makes it difficult to determine whether gentrifiers use non-motorized transport modes (NMTs) because of their political ideology or because of NMT-friendly infrastructure in the neighbourhood. Similar travel patterns will be difficult to find in Indian cities because of inadequate and hazardous NMT infrastructure and a traditional mind-set that sees the bicycle as a vehicle for the poor.

Kushto and Schofer (2008) conducted a study in Chicago to explore the relationship between gentrification and travel behaviour using both aggregate and disaggregate data. The unpublished study considers income, percentage of renter-occupied houses and education as gentrification indicators to differentiate gentrified CTs. It concludes that in spite of the same vehicle ownership patterns and PT accessibility, PT use in gentrified neighbourhoods is higher than that in non-gentrified neighbourhoods. However, despite considering most of the recognized gentrification indicators to identify gentrified CTs, the study is methodologically weak because it does not determine any factors that influence gentrifiers to use PT. Thus, the study results do not clarify whether the trend of higher PT use in gentrified neighbourhoods is due to the influence of the built environment of a neighbourhood or political ideologies that motivate gentrifiers to shift towards sustainable transit modes, as Danyluk and Ley (2007) highlight.

Pollack et al. (2010) explored the symbiotic relationship between transit and gentrification in a study conducted in the United States. The study assesses the change in population growth, housing units, racial and ethnic composition, household (HH) income, housing costs, in-migration rate, PT use, and motor vehicle ownership of transit rich neighbourhoods (TRNs) in various cities across the United States and compares it with their respective metropolitan statistical areas. They draw three conclusions: (1) there are significant changes in demographic and economic characteristics in TRNs; (2) unforeseen circumstances in TRNs reduce the density of groups most likely to use PT in favour of groups more likely to drive; (3) overall PT use increases at a slower rate (or, in some cases, declines at a faster rate) in TRNs than in metropolitan areas. Although the study assesses the influence of PT on socioeconomic characteristics and travel behaviour, it does not examine the influence of socioeconomic parameters on travel behaviour. Hence, it remains unclear whether the phenomenon of gentrification and the reduction in transit ridership occur simultaneously and whether they are interrelated. The effect of PT on changing travel patterns is also not established.

Dominie (2012) examined the effect of gentrification on commuters' choice of transit mode near station areas. The study considers income, occupation, education and ethnic composition as gentrification indicators and correlates them with transit ridership. It concludes that, the demographic changes associated with gentrification have a significant, negative association with transit use and a significant positive relationship with rates of driving alone (Dominie, 2012). Although the study successfully identifies the direct influence of various socioeconomic characteristics on transit ridership, it omits vehicle ownership which has a strong influence on transit ridership.

Thus, as this review indicates, these four studies exhibit mixed results, with two showing a positive correlation between gentrification and sustainable transit mode shares and two showing a negative correlation. All four studies focus on city level, use the aggregate data at CT level, regard change in various socioeconomic indicators as proxy to neighbourhood gentrification and establish the impact of gentrified neighbourhoods on transit mode shares.

While analysing neighbourhood level data, parameters other than socioeconomic indicators need to be controlled. These include built environment and land-use characteristics, which have a significant influence on travel behaviour. Unfortunately, these studies did not control the other parameters. In addition, none of these studies explore micro level details to understand the contribution of gentrifiers towards transit ridership and the impact of well-planned and competent PT on changing travel patterns of gentrifiers. To fill this gap, the current study attempts to evaluate the implication of the influx of wealthy residents on transit ridership at the micro level, using disaggregate HH data and metro-user survey data.

3 Research methodology

This section describes the case study area and data collection methods.

3.1 Yeshwanthpur Industrial Area, Bengaluru: a case study

To assess the impact of gentrification of station areas on transit ridership in Bengaluru, the Yeshwanthpur Industrial Area was chosen as the case study region. Study area boundaries were defined within a half-mile radius (~800 m) of a transit station, as it is the distance that most scholars recommend in defining TODs (Center for Transit Oriented Development, 2007; Guerra et al., 2011). The metro started operating in the study area from the year 2014. Currently in Bengaluru, a light rail transit is operating for a stretch of 32 km and a further stretch of 83 km is under construction (Bangalore Metropolitan Rail Corporation Limited, 2016). The housing demand in Bengaluru is high due to rapid urbanization and Information technology boom. To meet these demand within the span of 6 years (2009-2015) around 1689 multiunit projects are constructed adding approximately 400000 units. Out of these, 18% of projects are located with the 800m of transit station.

Historically, the study area is a working-class suburb and an important industrial hub of the city. Lately, however, owing to high-density policies, housing demand and metro accessibility, this neighbourhood is witnessing the construction of high-rise luxurious condominiums on vacant and brownfield lands. At the time of data collection in this neighbourhood, 1000 HHs were added in these condominiums; many more are under construction and in the planning stage as a result of the availability of land (see Figure 1).

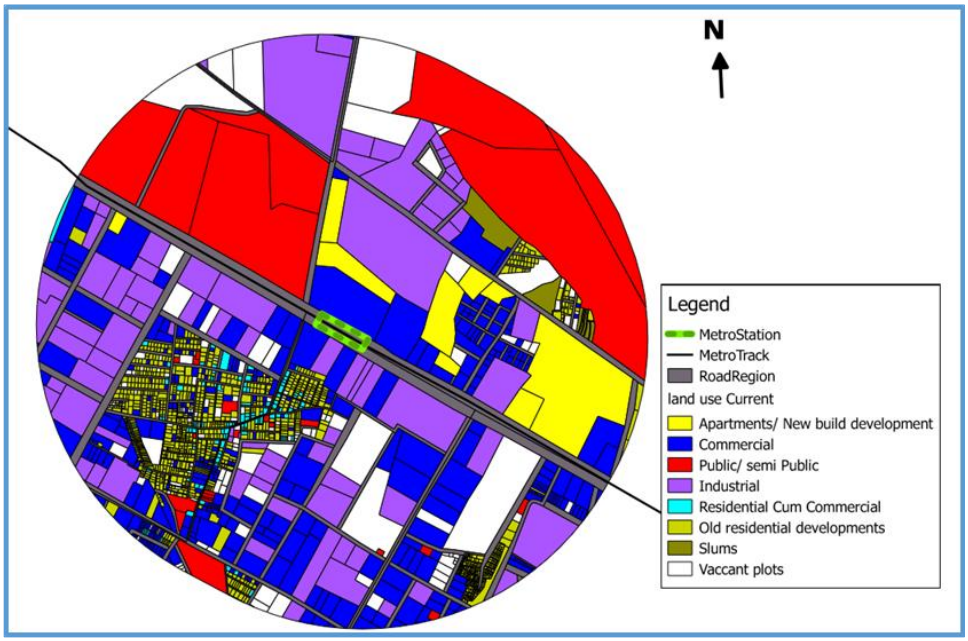

Figure 1: Study area boundaries within a half-mile radius of metro stations and current land-use characteristics

Source: Based on data from Indigo Consultants, Bengaluru.

3.2 Data collection

In order to assess the travel behaviour of various income groups, data for socioeconomic characteristics and travel patterns of gentrifiers and non-gentrifiers in the station area are needed. However, no such official data are available. Hence, a detailed door-to-door HH survey was conducted to collect the disaggregate data at HH level. The survey used a sample size of 10% of the population as Bruton (1985) recommends, and adopted a stratified random sampling technique for representation from both gentrifiers and non-gentrifiers. In addition, for spatial representation of each residential type in both residential areas, each 10th dwelling unit was visited. In multifamily building with more than 10 units, the first unit was visited and then the 11th unit was visited. For example if the building is a three storey house with 4 units in each floor unit no 101 visited and then the unit no 302 was visited. The total HHs in each stratum and sample size drawn are listed in Table 1. Four hundred questionnaires covered almost 1400 two-way trip profiles.

Table 1: Population statistics and sample size by location

Location/Income	Old residential area (non-gentrifiers)	New residential area (gentrifiers)
Total HHs within the study area	2956	954
Sample size drawn	300	100

Source: Author's compilation based on HH survey data.

Survey analysis of the housing and socioeconomic characteristics indicates that housing cost and rental values in the new residential area are higher than those in the old residential area. Compared to residents of the old neighbourhood, those of the new residential area are more likely to be professional workers and to have a university graduation. Ninety-five per cent of gentrifiers belong to a high-income group with an annual HH income above INR 500,000, whereas the majority in the old residential area has an annual HH income below INR 500,000 (Chava et al., 2016a). Variations in the socioeconomic profile support that the survey respondents from new residential areas are gentrifiers of the neighbourhood.

The preliminary analysis of travel patterns indicates that use of the metro among TOD residents is very less, as the metro network is not fully developed. Only few HH survey respondents indicated using the metro as a mode of travel. Therefore, the HH survey data are not enough to understand the impact of mass transit on changing travel behaviour of gentrifiers. Hence, to assess the influence of the metro, instead of using the HH level data a metro-user survey was conducted within the metro station premises. The survey was conducted for one working day and was able to capture responses of 150 metro users staying within the study area boundaries and using the metro as their mode of travel. These responses reflected travel behaviour of around 80 gentrifiers and 70 non-gentrifiers before and after metro operation. The influence of mass transit on changing travel patterns of TOD residents is well established in this metro-user survey analysis.

4 Empirical analysis

This section examines the effect of gentrification on travel behaviour and the effect of mass transit on changing travel patterns.

4.1 Travel behaviour of gentrifiers versus non-gentrifiers

In order to predict the contribution of gentrifiers and non-gentrifiers towards sustainable transportation goals, the travel behaviour of these two groups was compared in terms of mode shares, PT trip purpose, per capita trip rate, average trip lengths and vehicle ownership and transport cost burden (transportation cost/Income), with an emphasis on the reasons behind their travel behaviour.

The analysis of HH level survey data, as shown in Table 2, clearly indicates travel pattern differences between the two groups. With regard to PT mode shares, the bus mode share is lower and the metro mode share is much higher among gentrifiers than among non-gentrifiers. This may be due to the metro's high level of service (LOS) compared to bus services in terms of additional comfort, convenience, and saving travel time. The lower metro mode share among non-gentrifiers may be because of connectivity and affordability issues. Currently, the metro in Bengaluru connects to professional workplaces and shopping malls in urban areas (i.e. destinations that attract gentrifiers) but does not extend to the suburbs (i.e. where most informal working-class jobs accessed by non-gentrifiers are located). With regard to affordability, although the metro and bus services have similar fare structures, the metro lacks a fully integrated network and metro users have to depend on expensive and time-consuming last mile connectivity (LMC), making the metro service costlier than using buses. This trend might change with the completion of a well-integrated metro network.

Table 2: Comparison of travel patterns between new-build residential areas and local residential areas

	Local residential area (non-gentrifiers)	New-build high-rise residential area (gentrifiers)	
1. *Daily trips mode share (%)*			NA
• Walk	40	4	
• Cycle	<1	0	
• Two-wheeler	14	14	
• Autorickshaw	2	3	
• Car	1	57	
• Bus	41	5	
• Shared bus/car	<1	5	
• Metro	1	12	
2. *PT mode split by trip purpose (%)*			NA
• Work	74	48	
• Education	15	24	
• Recreational/shop	11	28	
3. *Daily per capita trip rate*	1.36	1.5	>0.05
4. *Average trip length (in km) (excluding walk)*	9.5	10.9	>0.05
5. *Vehicle ownership (per HH)*			
• Two wheeler	0.30	0.34	>0.05
• Car	0.05	1.11	<0.01
6. *Transport cost burden (%)*	2.21	3.23	<0.05

Source: Author's compilation based on HH survey data.

In contrast to the metro mode share, the walk mode share is very high among non-gentrifiers compared to gentrifiers. This trend can be attributed to land-use characteristics of the neighbourhood. Traditionally, residential neighbourhoods offer work, education and shopping opportunities. These mixed land-use characteristics enable the local residents (non–gentrifiers) to walk to their destinations. On the other hand, TODs are not mixed land-use developments like the traditional old residential areas. Hence, residents of these new high-rise developments depend either on personal vehicles such as cars and two-wheelers or on high-quality PT systems such as premium buses, the metro and intermediate public transport (IPT; e.g. autorickshaws) to reach their destinations.

Other travel patterns indicate that gentrifiers have a slightly higher trip rate and a greater trip length than non-gentrifiers. However, the difference is not statistically significant. Whereas two-wheeler vehicle ownership patterns are almost similar, car ownership among gentrifiers is much higher than among non-gentrifiers. The transport cost burden indicates that, the non gentrifiers are spending more percentage of their monthly income on transport than the gentrifiers. However, both of them are spending less than the 10% of their monthly income on transport, which is often referred as a benchmark to define the affordability of transport (Gomez and Echenique, 2007; Cervero, 2011). The less spending on transportation compared to the developed countries can be attributed to the short trip lengths, mixed land use, high proportion of walking trips, less usage of private vehicles, PT (bus) subsidies to the students and elderly people.

Overall travel behaviour analysis indicates that non-gentrifiers opt for more sustainable transit modes and their travel behaviour is in line with the three primary TOD objectives. Contrary to conventional thought, the metro mode share among gentrifiers is high. Nevertheless, to achieve sustainable transportation goals, there is a need to introduce policy measures to further increase sustainable mode shares among TOD residents, especially among newly moved residents. Policy measures can include bringing in land-use diversity to encourage more walking, especially among the affluent; improving the built environment to boost cycling; developing an accessible and affordable metro network for further increasing the metro mode share among non-gentrifiers and gentrifiers. In addition, to ensure the same access benefits for the poor, there is a need to include affordable housing in the new high-rise developments. A detailed understanding of the stumbling blocks in choosing the metro as a mode of travel and the metro's influence on sustainable transport objectives is provided in subsequent sections.

4.2 Influence of gentrification indicators on choice of PT (≈bus) mode

To examine the influence of gentrification indicators on transit ridership, this section discusses the influence of socioeconomic indicators associated with PT commuting. These include HH location, motorized vehicle ownership, income, occupation, education, age, house ownership and gender (for more literature on gentrification indicators, refer to (Chava et al., 2016a). The effect of each indicator on PT mode shares was assessed in

relationship to the remaining indicators kept at a constant. In the HH survey as very few metro trips were captured compared to the number of bus trips, the analysis reflects the influence of gentrification indicators on the bus as a mode of travel. As the HH survey data was inadequate to assess the influence of socioeconomic indicators solely on the metro, a detailed metro-user survey was conducted to further understand the effect of TOD residents on metro ridership.

Of all the gentrification indicators highlighted, housing location of the survey respondents strongly influences travel choices: local area residents used PT for 42% of daily trips whereas those in new residential HHs used PT for 19% of trips. A relatively high PT share was also found among HHs with zero vehicle ownership: zero-vehicle HHs used PT for 51% of daily trips whereas two-vehicle HHs used PT for 16% of trips. Regarding income, respondents with an income < INR 300,000/annum made 40% PT trips whereas those with an income > INR 750,000/annum made 14% PT trips. Education level also shows some influence on PT ridership: HHs with zero graduates made 40% PT trips whereas HHs with more than two graduates made 26% PT trips. Gender comparisons reveal female respondents made 34% PT trips whereas male respondents made 45% PT trips. Interestingly, no strong pattern emerged for the relationship between occupation, age and HH ownership and PT mode choice.

The visibly increasing trend of choosing private transport over PT may be because the current PT system (mostly bus) in Indian cities offers users poor quality and unsafe services. Hence, as the social status improves (i.e. higher levels of education, income, vehicle ownership), the willingness to use existing PT modes declines (Tiwari, 2011). This trend can change with the introduction of a well-planned and well-designed mass transit system, as the metro can compete with private modes of transport in terms of improved travel time, comfort, safety and security. In fact, the metro has a better LOS than private vehicles, as overall travel times are lower than that of private vehicles.

4.2.1 Model for predicting PT (≈bus) choice

A statistically significant binary logistic regression model was developed for predicting the probability of choosing PT among metro station area residents in the Yeshwanthpur Industrial Area. The model helps to understand the cumulative effect of all the variables

(gentrification indicators) discussed in the previous section and reduce the influence of correlative variables. According to this model, the general equations to predict the probability of an event (using PT) to occur are:

$$\pi_i = e^{z_i} \div (1 + e^{z_i}),$$

$$\text{logit}(\pi_i) = \ln[\pi_i \div (1 - \pi_i)] = z_i = b_0 + b_1 x_{i1} + b_2 x_{i2} + \ldots\ldots + b_P x_{ip},$$

where π_i is the probability of choosing PT (bus); x_{ij} is the jth predictor for the ith case; b_j is the jth coefficient; and p is the number of predictors.

The socioeconomic factors that show significant impact on PT use were considered in the model as predictive variables of PT mode choice. The factors included age, HH location, vehicle availability per HH, HH income and number of graduates per HH. To control the influence of PT availability on choosing transit mode, initially the availability of a PT network was also considered as a predictive variable; however, later network availability parameters were omitted from the model as the HH survey found these had no (or insignificant) influence on PT use. Regarding the bus network availability parameter, Bengaluru has a very dense bus route network and bus services are widely available across the city, so availability of buses does not influence PT usage. In the case of the metro network availability parameter, metro use is less in absolute numbers because of the small sample size and the parameter shows no significant influence on PT usage. Hence, the two variables were omitted from the analysis.

Gender and location variables were coded as categorical variables and the remaining variables were considered to be continuous variables. Predictive and estimated variables were coded as follows: independent/estimated PT use was coded as a dichotomous variable (using = 1, not using = 0). Gender was coded as 1 = male, 2 = female. To account for PT use variations between the old and new residential areas a dummy variable was included to indicate whether the HH is located in the new residential area or the old residential area (1 = new residential area, 2 = old residential area).

To avoid redundant parameters, the model adopted the reference cell method. In the case of categorical and dummy variables, the first category was assumed as the reference category and set as 0. For example, if α_i is the effect of location factor on PT use and the

trips generated in new residential areas are considered as reference variables and set as $\alpha_1 = 0$, then other trips generated in old residential areas are interpreted as α_i for $i = 2$, which represents the impact of old residential locations on PT use compared to new residential locations (German, 2007).

The resulting model as shown in Table 3 indicates that education has no significant impact on PT mode choice and confirms the prominent impact of settlement code (i.e. whether station area residents stay in the old or new residential area), gender, vehicle per HH and HH income on mode choice. Among the predictive variables, the strongest predictor of PT use is vehicle availability, followed by settlement code; other factors in the model also show significant impact on PT mode choice.

Table 3: Binary logistic regression model to predict the likelihood of commuting by public transit (≈bus) with respect to various socioeconomic characteristics

Predictive variable	B	SE	Wald	Significance	Odds ratio
Settlement code	0.562	0.274	4.234	0.039	1.754
Sex	0.539	0.182	8.793	0.003	1.715
Vehicle per HH	–1.502	0.297	25.588	0.000	0.223
HH income	0.336	0.109	9.436	0.002	0.715
Constant	–1.601	0.513	9.739	0.002	0.202

Note: HH income categories are 1 = <INR 300,000; 2 = INR 300,000 to 750,000; 3 = INR 750,000 to 1,500,000; 4 = >INR 1,500,000. Model summary: $N = 659$ ($df = 4$); $\chi^2 = 88.4$; significance = 0.000.

Source: Author's compilation based on HH survey data.

The odds ratio of the settlement code indicates that the probability of survey respondents staying in old residential areas using PT is almost twice as high as respondents from new residential areas. Similarly, the probability of male respondents using PT is twice as high as female respondents, because most women in the study area are homemakers and their primary mode of travel for shopping/recreation is walking.

To understand the net influence of continuous variables using the model results, the sensitivity of PT use with regard to the predictive variables of income and vehicle ownership was plotted, setting the other predictive variables to zero. As the probability

graph in Figure 2 shows, increasing vehicle availability and income level per HH in station areas decreases the likelihood of residents using PT.

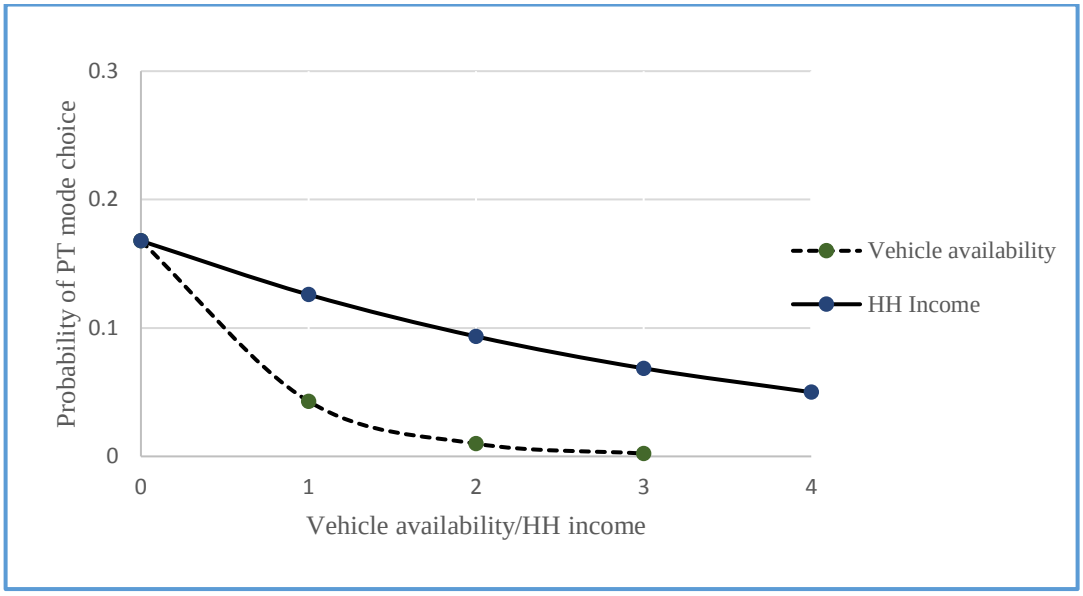

Figure 2: Sensitivity of PT (≈bus) mode choice to vehicle availability and income level per HH

Source: Author's compilation based on HH survey data.

In summary, it is clear that gentrification is negatively correlated with PT ridership. This may be because most current PT trips captured were bus trips, which has a poor LOS compared to other private modes of travel, IPT modes and the metro. As income levels and the capacity to own a vehicle increases, the willingness to use buses is observed to fall drastically. However, the impact of socioeconomic factors in choosing the metro varies, and its high LOS makes the metro an attractive PT mode choice for the affluent. To better understand this phenomenon, a detailed metro-user survey was conducted. The analysis of the survey data is presented in the next section.

4.3 Mass transit influence

This section aims to understand the impact of the metro on the travel behaviour of gentrifiers and non-gentrifiers, and eventually on sustainable transportation goals. First, shift in mode choice among gentrifiers and non-gentrifiers after introducing the metro and the underlying reasons for change in travel behaviour are analysed. Second, issues that

need to be examined further for increasing metro ridership are explored. Finally, an estimate of the potential ridership is provided based on the assumed resolution of respondent-raised issues.

The mode of travel prior to metro construction, as shown in Figure 3, indicates that majority of non-gentrifiers currently using the metro were previously bus users whereas majority of gentrifiers currently using the metro were previously IPT users. In addition to it, the analysis also reflects that 10% of the metro trips made by gentrifiers are induced trips by the availability of metro and this figure is 16% among non gentrifiers. Similar trends are observed in the studies conducted on Delhi metro, where 51% of the metro users are previously bus users and 28% are private vehicle users and 13-18% of the trips were induced (Chauhan et al., 2016; Goel and Tiwari, 2016).

Although gentrifiers were noted to have one car per family, a single car may not fulfil all HH mobility needs as survey HHs had an average of three people. Hence, IPT and premium buses become popular modes of travel for HH members without a personal vehicle. However, this trend is slowly changing with the introduction of the metro and its high LOS appeal compared to other PT modes.

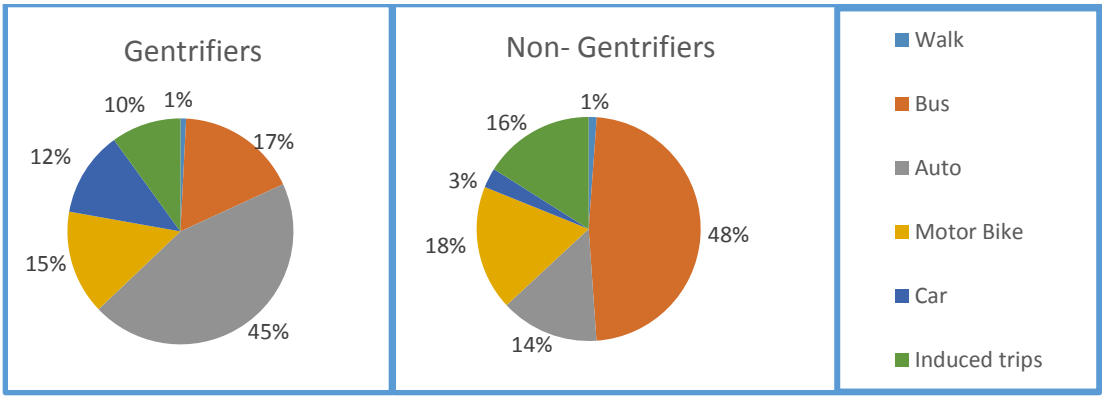

Figure 3: Metro user's mode of travel before the metro

Source: Author's compilation based on metro-user survey data.

The survey revealed that users' primary reason for shifting from other modes of travel to the metro was the similar fare structure and improved LOS compared to buses and IPT.

However, the egress trip mode shares as highlighted in Figure 4 show that the metro is becoming a competitor with other travel modes only for trips with destinations located within walking distance of metro stations. This trend may be because of the additional fare and time associated with accessing other private, IPT and PT modes. Hence, the willingness to use the metro may increase if the full network is developed and integrated with other modes of travel.

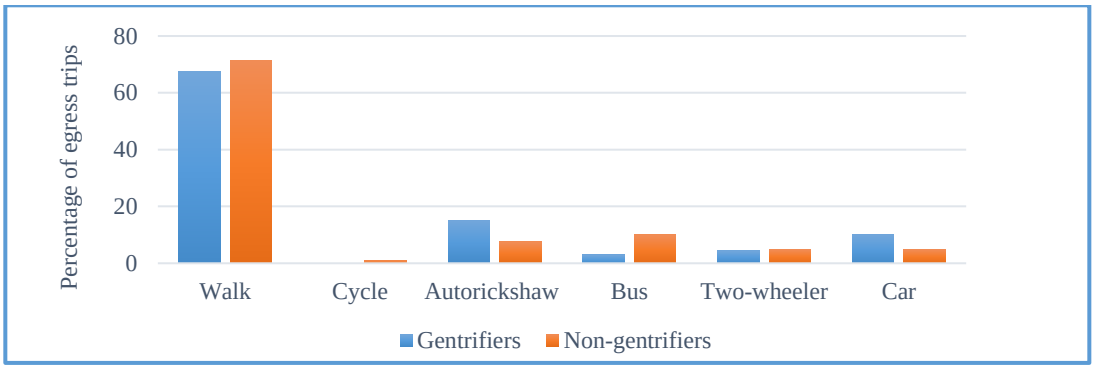

Figure 4: Egress trip mode shares

Source: Author's compilation based on HH survey data.

In order to optimize metro ridership, it is important to understand the issues that act as stumbling blocks in choosing the metro as a mode of travel. HH survey respondents were asked to state at least three reasons for not choosing the metro as their mode of travel. As the metro network in Bengaluru is not fully developed, expectedly > 60% of respondents highlighted lack of availability/ accessibility of the metro as the primary reason. Gentrifiers listed other reasons as lack of privacy and time-consuming and unsafe LMC, whereas non-gentrifiers highlighted lack of subsidised fare system similar to the buses, expensive LMC, lack of feeder services and time-consuming LMC, in order of importance. The metro-user survey data indicate that for the metro to attract either gentrifiers or non-gentrifiers TODs need to improve built environment for safe access to the metro station and integrate with other travel modes to provide seamless movement to all residents. . The integration policy needs to ensure the fare integration as well. Currently buses are offering subsidised passes to the students and elderly people and also providing monthly passes for long distance daily travellers. However, metro has a similar fare structure for all the users. Though for single trips the fare for buses and metro are

similar, for the above mentioned segments, buses are providing affordable transport. Hence, to provide the benefits of the metro to these segments, there is a need to bring in uniform fare policy for all the PT modes.

To identify potential transit ridership, HH survey respondents currently using other private, IPT and PT modes were asked about their willingness to use the metro when the network is fully developed and made safe, accessible and affordable. The analysis indicates that most bus and IPT users among both gentrifiers and non-gentrifiers are more willing to choose the metro than other private mode users. Interestingly, contrary to conventional thought, a few gentrifiers using cars expressed willingness to use the metro if it saved travel time, although majority of private car users expressed reluctance to shift from private modes of travel to the metro because of privacy concerns. Overall As shown in Figure 5, non-gentrifiers are more willing to use the metro than gentrifiers. Although some gentrifiers expressed willingness to use the metro in the future, the probability of them shifting to the metro is lower than the non-gentrifiers.

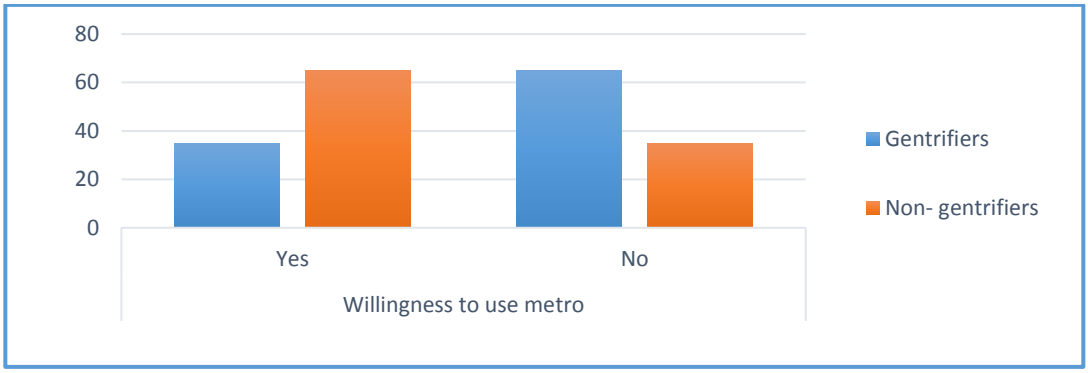

Figure 5: Potential transit ridership when the metro network is fully developed

Source: Author's compilation based on HH survey data.

Overall, analysis of mass transit influence demonstrates that the metro is successful in attracting bus and IPT users (if the fares are similar) whose destinations are located within walking distance of metro stations, as well as a small fraction of private vehicle users. Even a small number of private vehicle users shifting to the metro can contribute significantly to the reduction of congestion and emissions. The factors mainly influencing willingness to use the metro include private vehicle availability, metro network availability, affordability and LMC. Although the current metro mode share is small in

the overall PT mode share ridership numbers may increase drastically when the network is fully developed and fare and LMC issues are addressed through integration measures. Contrary to conventional thought, study analysis revealed that the metro has a strong influence on changing travel patterns of gentrifiers, especially those who do not have private vehicles. For example, a (gentrifier) HH with one car and three family members having different travel needs (work, education and shopping) will depend on other modes of travel. In this case, two members of the family have the highest probability of choosing the metro over other PT modes. Thus, the study concludes that gentrifiers can contribute significantly towards metro ridership and a well-planned and integrated metro network can change the perception of gentrifiers towards the PT system.

5 Policy implications

The study findings suggest that the majority of local area residents are continuing to use sustainable transport modes compared to residents of new-build developments however the wealthier new build gentrifiers are also using cars less than they would usually based just on socio-economic considerations. Gentrifiers are willing to use the metro where the possibility of avoiding traffic is available. The willingness of gentrifiers to use the metro is based on conditions of additional comfort, convenience and saving travel time compared to other PT modes. Although the metro can change travel behaviour of gentrifiers, the willingness to use the metro is higher among non-gentrifiers than among gentrifiers.

Based on these findings the study concludes that for sustainable transport benefits TOD density policy needs to be balanced with equity considerations. If new-build developments are to reap significant metro ridership benefits, the TOD density policy must include affordable housing policies to accommodate people with low income and low vehicle ownership, as their willingness to use the metro is higher than affluent residents in these developments. For the metro to attract more TOD residents it is necessary to expand the metro influence area beyond walking distance destinations by integrating with other existing modes of travel such as bicycles, IPT and buses. In addition fare integration measures needs to be taken to ensure metro access benefits for all.

To accommodate affordable housing in TODs, it is necessary to divert some government revenue increases and private developer profits towards funding transit and social housing projects through innovative value capture mechanisms as practised in Bogota, Hong Kong, California and Montgomery County. In Bogota, land close to transit stations was acquired and social housing constructed much before announcing the transit network. The city also receives 30–50% of increased land values due to government investments in transit (Suzuki et al., 2013). In Hong Kong, transit agencies sold station area land holdings to private developers for higher 'after-rail' prices and negotiated the provision of public and subsidized housing as part of TODs (Cervero and Murakami, 2009). In the United States, while California adopted public–private partnership strategies in developing social housing around station areas (Cervero, 1994), city authorities in Montgomery County mandated developers provide 12.5–15% affordable housing in exchange for a 22% density bonus (Center for Transit Oriented Development, 2009). These are a few examples where social housing has been successfully integrated with transit investments to address equity issues and optimize transit ridership. To achieve these objectives in Bengaluru, city authorities need to come up with similar innovative policy measures and strategies applicable to the local context in collaboration with station area residents and developers.

As highlighted in this analysis, apart from providing affordable housing in TODs to accommodate transit dependents, expanding the metro influence area beyond destinations at walking distance using mode integration and introducing uniform fare structure will have a substantial impact on increasing metro ridership, as poor last mile connectivity and unaffordability are the reasons for TOD residents not choosing the metro as a mode of travel. Examples from Hong Kong and Singapore are useful in this regard (Lo et al., 2008; Booz & Company, 2011); in both cities the role of each transit mode is specific and operates complementary to each other and has uniform fare structure.. As a result, both cities have successfully provided faster, cheaper and comfortable LMC to mass transit systems. In Perth, the new Southern Railway is similar to Bengaluru's Metro and is highly successful in patronage as it has fully integrated buses and car drop-offs into their station precincts thus extending the influence of the train well beyond walking catchments (McIntosh, Newman, et al., 2013) and has same fare structure for buses and rail. Thus,

Bengaluru too needs to implement policy measures to integrate the metro with existing modes for improved door-to-door and affordable transport services.

Cities need to be more equitable and more sustainable. This study has confirmed that the Metro expansion in Bengaluru is indeed improving sustainability but needs more affordable housing policy in its new build TODs as well as greater integration of other modes to station precincts.

References

Atkinson, R., 2000. Measuring Gentrification and Displacement in Greater London. Urban Stud. 37, 149–165.

Bangalore Metropolitan Rail Corporation Limited [WWW Document], 2016. URL www.bmrc.co.in

Booz & Company, 2011. Integrating Australia's Transport Systems : A Strategy for an Efficient Transport Future. Infrastructure partnership Australia.

Center for Transit-Oriented Development, 2009. Mixed-Income Housing Near Transit: Increasing Affordability With Location Efficiency. Washington D.C.

Cervero, R., 2011. State Roles in Providing Affordable Mass Transport Services for Low - Income Residents, in: International Transportation Forum. 25- 27 May, Leipzig, Germany.

Cervero, R., 2010. Transit Transformations: Private Financing and Sustainable Urbanism in Hong Kong and Tokyo, in: Ascher, W., Krupp, C. (Eds.), Physical Infrastructure Development: Balancing the Growth, Equity and Environmental Imperatives. Palgrave Macmillan, New York, pp. 165–185.

Cervero, R., 2007. Transit-oriented development's ridership bonus: a product of self-selection and public policies. Environ. Plan. A 39, 2068–2085. doi:10.1068/a38377

Cervero, R., 1994. Transit-based housing in California: evidence on ridership impacts. Transp. Policy 1, 174–183. doi:10.1016/0967-070X(94)90013-2

Cervero, R., 1993. Ridership Impacts of Transit-Focused Development in California. The University of California Transportation Center, Berkeley.

Cervero, R., Kockelman, K., 1997. Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon 2, 199–219.

Cervero, R., Murakami, J., 2009. Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Stud. 46, 2019–2043. doi:10.1177/0042098009339431

Chapple, K., 2009. Mapping Susceptibility to Gentrification : The Early Warning Toolkit. Berkeley, CA: Center for Community Innovation.

Chauhan, V., Suman, H.K., Bolia, N.B., 2016. Binary Logistic Model for Estimation of Mode Shift into Delhi Metro. Open Transp. J. 10, 124–136. doi:10.2174/1874447801610010124

Chava, J., Newman, P., Tiwari, R., 2016. Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore. Curtin University Sustainability Policy Institute, Curtin University, Perth, WA.

Danyluk, M., Ley, D., 2007. Modalities of the New Middle Class: Ideology and Behaviour in the Journey to Work from Gentrified Neighbourhoods in Canada. Urban Stud. 44, 2195–2210. doi:10.1080/00420980701520277

Davidson, M., 2007. Gentrification as global habitat: a process of class formation or corporate creation? Trans. Inst. Br. Geogr. 32, 490–506. doi:10.1111/j.1475-5661.2007.00269.x

Davidson, M., Lees, L., 2005. New-build gentrification and London's riverside renaissance. Environ. Plan. A 37, 1165–1190. doi:10.1068/a3739

Dominie, W., 2012. Is Just Growth Smarter Growth ? The effect of Gentrification on Transit Ridership and Driving in Los Angele's transit station area Neighborhood. University of California, Berkley.

Feinstein, B.D., Allen, A., 2008. Article Community Benefits Agreements with Transit Agencies : Neighborhood Change Along Boston's Rail Lines and a Legal Strategy for Addressing Gentrification. Transp. law J. 38, 85–114.

Freeman, L., Braconi, F., 2004. Gentrification and Displacement. J. Am. Plan. Assoc. 70, 39–52.

Goel, R., Tiwari, G., 2016. Access-egress and other travel characteristics of metro users in Delhi and its satellite cities. IATSS Res. 39, 164–172. doi:10.1016/j.iatssr.2015.10.001

Gomez, A., Echenique, L., 2007. Affordability of Public Transport: A Methodological Clarification. University of Las Palmas of Grand Canary.

Government of Karnataka, 2009. Amendment to the zoning regulations of master plan of Bangalore. UDD 93 MNJ 2008, India.

Grube-cavers, A., Patterson, Z., 2015. Urban Rapid Rail Transit and Gentrification in Canadian Urban Centres – A Survival Analysis Approach. Urban Stud. 50.

Guerra, E., Cervero, R., Tischler, D., 2011. The Half-Mile Circle: Does It Best Represent Transit Station Catchments? Report, Institute of Transportation Studies, University of California, Berkeley.

He, S., 2010. New-Build Gentrification in Central Shanghai: Demographic Changes and Socioeconomic Implications. Popul. Space Place 361, 345–361.

Hendricks, S.J., Winters, P., Wambalaba, F., Barbeau, S., Catala, M., Thomas, K., 2005. Impacts of Transit Oriented Development On Public Transportation Ridership. National Research council, washington, D.C, Report, Center for Urban Transport reserach, University of South Florida, Tempa.

Jillella, S., Matan, A., Newman, P., 2015. Participatory Sustainability Approach to Value Capture-Based Urban Rail Financing in India through Deliberated Stakeholder Engagement. Sustainability 7, 8091–8115. doi:10.3390/su7078091

Kahn, M.E., 2007. Gentrification Trends in New Transit-Oriented Communities : Evidence from 14 Cities That Expanded and Built Rail Transit Systems. Real Estate Econ. 35, 155–182.

Kushto, E.R., Schofer, J.L., 2008. Travel and Transportation Impacts of Urban Gentrification: Chicago, Illinois Case Study. Northwestern University, Evanstion, Illinois.

Lin, J., 2002. Gentrification and Transit in Northwest Chicago. J. Transp. Res. Forum 56, 175–191.

Lo, H.K., Tang, S., Wang, D.Z.W., 2008. Managing the accessibility on mass public transit : The case of Hong Kong. J. Transp. Land Use 2, 23–49.

Lund, H., 2006. Reasons for Living in a Transit-Oriented Development, and Associated Transit Use. J. Am. Plan. Assoc. 72, 357–367.

Lund, H., Cervero, R., Willson, R.W., 2004. Travel Characteristics of Transit-Oriented Development in California. Report, The University of California Transportation Center, Berkeley.

McIntosh, J., Newman, P., Glazebrook, G., 2013. Why Fast Trains Work: An Assessment of a Fast Regional Rail System in Perth, Australia. J. Transp. Technol. 3, 37–47. doi:10.4236/jtts.2013.32A005

Mckibbin, M., 2011. The influence of the built environment on mode choice – evidence from the journey to work in Sydney, in: Australasian Transport Research Forum 2011. Adelaide, Australia, pp. 1–12.

Newman, P., Kenworthy, J., 2015. The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning. Island Press, Washington D.C.

Pollack, S., Bluestone, B., Billingham, C., 2010. Maintaining Diversity In America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change. Dukis Center for Urban and Regional policy, Northeastern University.

Pucher, J., Renne, J.L., 2003. Socioeconomics of Urban Travel: Evidence from the 2001NHTS. Transp. Q. 57, 49–77.

Rérat, P., Söderström, O., Piguet, E., 2010a. New Forms of Gentrification: Issues and Debates. Popul. Space Place 10, 335–343. doi:10.1002/psp.585

Rérat, P., Söderström, O., Piguet, E., Besson, R., 2010b. From Urban Wastelands to New-Build Gentrification : The Case of Swiss Cities. Popul. Space Place 10, 429–442.

Smith, N., 1982. Gentrification and Uneven Development. Econ. Geogr. 58, 139–155. doi:10.2307/143793

Suzuki, H., Iuchi, K., Cervero, R., 2013. Transforming cities with transit: Transit and Land-Use Integration for Sustainable Urban Development. World Bank, Washington DC. doi:10.1596/978-0-8213-9745-9

Tiwari, G., 2011. Key Mobility Challenges in Indian Cities, in: International Transport Forum. 18-20 May, Leipzig, Germany.

Visser, G., Kotze, N., 2008. The State and New-build Gentrification in Central Cape Town, South Africa. Urban Stud. 45, 2565–2593. doi:10.1177/0042098008097104

Journal paper 3: Stakeholder deliberation on developing affordable housing strategies: towards inclusive and sustainable transit oriented developments.

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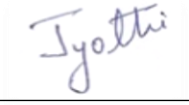

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Article

Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit Oriented Developments

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Abstract: Transit oriented developments (TODs) are commanding high land and rental value due to improved accessibility and economic opportunities. Owing to the increase in land and rental value, the highly desirable TODs are gradually becoming inaccessible to the poor, creating social exclusion and housing inequities within the TODs. To address this consequence, the study proposes a three-level stakeholder deliberation framework (inform, involve and collaborate) towards developing inclusive housing strategies for equitable and sustainable TODs. The framework is applied to the context of Yeshwanthpur industrial area, Bengaluru, India. The first level of deliberation 'information' foregrounds the need for affordable housing strategies for stakeholders. In the second level of deliberation, the stakeholders involved identify the major challenges in incorporating affordable housing into TODs. In the third level of deliberation, stakeholders collaborate to contemplate strategies to combat each challenge. The results show that mandatory inclusionary zoning, special purpose planning vehicles, land banking entities, innovative financing tools, and local area level plans in collaboration with the community, emerged as potentially feasible strategies to create inclusive housing outcomes in the TOD case study area.

Keywords: inclusive TODs; affordable housing strategies; stakeholder deliberation; sustainable TODs

1. Introduction

Transit—and its associated transit oriented developments (TODs)—is emerging as a sustainable solution to address various transportation and rapid urbanization issues facing cities [1,2]. By definition, TOD stands for enabling compact, mixed land use, and non-motorized transport (NMT) outcomes within the 500 m to 800 m radius of centrally located transit stations [3,4]. TODs present significant market opportunities—absent in car dependent urban fabric [1]—but these can only be realised if cities provide the necessary planning structures, in terms of zoning, land assembly and other regulatory enablers. These enablers, combined with TOD amenities and high-quality public transit accessibility, are generating demand for transit neighbourhoods, and inevitably increasing land and rental values. Cities frequently use the TODs' potential to raise land value to capture this transit generated land value, and invest it to finance transit and social infrastructure [1,5].In the absence of inclusive affordable housing strategies, the high land and rental value of TODs induces displacement or exclusion of the poor from the

coveted TOD areas [6,7,8,9,10]. The phenomenon of the exclusion of the poor and their replacement by the affluent due to housing inequities, is referred to as gentrification [8,11,12,13].

Although some cities have a few affordable housing implementation programmes in place, they often prefer peripheral areas to locate such housing units due to lower land costs [14][15][16]. However housing affordability is not the same as living affordability as transportation costs increase greatly [17][18]. The occupants of these units can end up losing their livelihood by relocating farther from urban opportunities[19][20]. According to Litman, "Housing is not really affordable if located in isolated areas with high transportation costs. True affordability therefore requires affordable-accessible housing"[21], (p. 10). Integrating affordable housing with affordable transport yields equitable TODs. It can also contribute significantly to transit ridership, as the poor who do not have access to private vehicles are more dependent on transit [22].

The process of incorporating affordable housing in TODs can be complex, given the high production cost, and the involvement of multiple agencies (transit, housing, municipality, state, bankers, private investors, landowners, and local and national governments). This process is more complicated in developing countries—like India where the case study in this research project takes place—due to the lack of coordination and regulations, and minimal experience with mass transit and its TOD opportunities [23].

In many developed cities, gentrification in TODs has been researched for some time as they have been dealing with it since the mid-20th century [24][25][26]. To combat the gentrification related issues in TODs, cities in developed countries have adopted a combination of strategies and innovative tools based on the opportunities, challenges and legislation governing their transit neighbourhoods [6]. For example, BART, California, USA began converting parts of its large parking lots in TODs to mid-rise affordable housing [27]. Inclusive TODs were further catalyzed through development incentives for TODs such as parking reduction, high floor area ratio (FAR), relaxed open space requirements, and public subsidies. In another example, in the Hong Kong 'rail+property' (R+P) program, the transit and housing authorities actively participated in real estate activities around the station area, which yielded sustainable and inclusive TOD developments [28][29]. Similar projects have been implemented in Singapore as well [30].

Since each TOD has unique characteristics, the strategies and tools applicable to one TOD many not be relevant to another [31][32]. The characteristics include location, economic opportunities, land use characteristics, density, design, market strength, redevelopment opportunities, and more [32]. The variation in TOD types is probably greater in developing countries than the developed ones, due to vast differences in the above listed neighborhood characteristics, but in almost all cases developing countries are unlikely to have the extensive issues of density and land use mix associated with redevelopment [33].

Identifying the strategies suited to the local context, based on the local TOD characteristics, is crucial for inclusive TOD planning. Traditionally, these strategies have been determined by urban planners, based on manuals or guidelines on mixed income TODs [34]. The implementation of these strategies is often minimal, due to the lack of coordination and collaboration among multiple agencies involved in the TOD planning. The study proposes.—alternatively to traditional planning—a framework for a stakeholder deliberation, which facilitates collaboration with the stakeholders in identifying feasible strategies towards equitable TODs. This innovative process provides meaningful opportunities for stakeholders to engage in a dialogue and share their views from the planning stage onwards. This process transforms the stakeholders' role in the traditional planning process from combative and divisive to cooperative and collaborative; Hartz-Karp calls this co-intelligence [35]. It generates communitywide buy-in and enhances the odds of stakeholders supporting inclusive TOD goals and implementing the corresponding strategies [23][36].

The proposed stakeholder deliberation framework developed in the study is applied in the context of Yeshwanthpur industrial area metro station, Bengaluru, to identify affordable housing strategies to mitigate the emerging TOD inequities.

2. Literature review:

This section provides further insights on TOD concepts, gentrification issues in TODs and the exiting tools—adopted in developed countries—to mitigate them.

2.1 TOD: concept and its adoption by various countries

TODs are being embraced as a means to focus the rapidly growing urban population around a well-planned transit system [1]. They encourage the use of public transport and NMT, and discourage that of private vehicle(s). Further, cities are adopting the TOD concept as an innovative financial tool to direct capitalized land values towards investing on transit and other social infrastructure [5]. The TOD concept was first introduced in the USA, to enable more socially, environmentally and economically sustainable communities. In the USA, TODs are often planned as single node TODs, which focus only on the 3Ds concept (density, diversity and design), within the 800m radius of a centrally located transit station. Though developed as mixed use TODs, in practice they are often used for mono-functional purposes [37].

The TOD concept was widely recognized as a sustainable urban transport solution and adopted by other regions across the globe. In many European countries the term TOD is rarely used, however, its concept has been incorporated in urban planning for many decades, albeit with other names [38][39]. Unlike the USA, European countries develop TODs as multi node TODs, which are similar to single node TODs, except that they go beyond a single location, to create a regional network of nodes around rail stations [38][40]. They focus on the 6Ds concept (density, diversity, design, destination, distance, and demand management), to realign all urban regions around rail transport, away from car as a mode of travel [37][41]. However, the recent economic crisis in Europe has prioritized market led economic developments over planning based developments. Hence, efforts to implement TODs in European cities are losing momentum [39]. Despite these difficulties, most of planners are still positive about the future of TOD in European cities.

Few Asian countries are also successfully implementing TODs. Hong Kong's R+P program best illustrates the successful implementation of multi node TODs. The first generation R+P programs focused only on the density concept, neglecting the other TOD concepts. Later however, the downward trend of real estate prices coupled with people's unwillingness to use transit prompted Hong Kong's transit authorities to incorporate high quality design, place making, and land use diversity in the next generation R+P programs [29]. Chinese cities are also taking to multi node TODs as an alternative form of urbanism, to reduce over-reliance on private automobile(s) [2][42][43].

Following the example of many developed and developing countries, Indian cities are also incorporating the TOD concept in urban planning [43]. The primary focus of these TODs is densification to increase transit ridership and raise funds for transit infrastructure. Though the TODs are cashing in on the land value in stations areas and ensuring proximity to transit, however, from neglecting all other D-variables, they may not yield liveable, walkable, sustainable and healthy neighbourhoods [44].

While implementing the various TOD aspects highlighted above, often planners do not focus on inclusive densities or mixed income developments. As a result, the highly desirable TODs are observed to exclude and replace the poor—by the affluent—thus creating gentrification [45]. Unfortunately, the existing literature does not focus on gentrification issues in TODs in the

developing world, as gentrification has only recently become an emerging issue there. However, developed countries offer a few studies. The next section summarises these studies.

2.2. Gentrification in TODs:

TODs are attractive both as residential as well as working spaces due to the various benefits they offer. This increase in demand for TODs attracting higher capital investments [46] and increasing land and rental values [1][5][47] [48][49]. The higher housing cost of new developments and the increase in rental values of old ones can render the coveted TOD areas unaffordable for the poor, who will therefore remain excluded from the new developments and be replaced by the affluent in the older ones and thus create gentrification issues [9][10][50]. There were very few studies which have focused on the process of gentrification in TODs in developed countries.

Firstly, Kahn conducted a study in 14 cities in the US. He considered change in average home prices and the share of the college graduates before and after transit operations were gentrification indicators. The study concluded that there was greater gentrification near the walk and ride transit stations than the park and ride transit station [9]. Secondly, Feinstein and Allen conducted a study in the Boston metropolitan region in the US. They considered the education, income, and households receiving public assistance, the influx of new residents were proxies to the gentrification. The study results shows that the extension of rail lines compels less affluent long established residents in rental housing to move due to increases in housing costs [7]. Thirdly, Grube-cavers and Patterson conducted a study in Canada. They considered education, income, house rent, occupation, and percentage of owner occupied housing are proxies to gentrification. The study concluded that rail transit has had a significant impact on gentrification [51].

All the aforementioned studies focused on developed countries. Unfortunately, the examination of gentrification in TODs has received relatively little attention in developing countries. There is also therefore little written on strategies to mitigate inequity in the developing world context. A recent study conducted in Bengaluru illustrates that housing units in the new TODs cost 68% more than the houses located in the suburbs. Due to high price and larger unit sizes, the new TODs are excluding the poor and are providing them only for the affluent, thus undergoing new build gentrification. The residents of these new TODs are wealthy, highly qualified professionals with a high vehicle ownership rate [8]. It is evident from the study that developing countries which are traditionally characterized by neighborhoods which are mixed income in nature are also undergoing gentrification. To combat the gentrification related issues in TODs, cities in developed countries adopt various strategies and innovative tools. Though these might not be directly applicable to other TODs (in developing countries), they can inspire and guide the development of existing or new tools applicable to the local context. The next section describes the strategies and tools adopted in cities from the developed world.

2.3. Existing tools and case cities adopting them:

Developed countries facing severe gentrification issues since the mid-20th century have implemented various housing strategies and tools—especially in TODs—with the objective of reducing both housing and transportation costs. This section highlights a few such tools to guide the stakeholders in identifying the affordable housing strategies in the case study area. Shoemaker classified these tools broadly under three categories, listed below [52]

(1) Tools related to zoning regulations, local codes, fees and procedures;
(2) Financing tools; and
(3) Joint development programs tools

2.3.1. Tools related to zoning regulations, local codes, fees and procedures:

This section highlights the tools related to change in regulations, local codes and approval procedures, to incorporate affordable housing in TODs.

a. ***Inclusionary zoning ordinance:*** The ordinance functions essentially as a trade-off between the government and the developers, with the series of predetermined parameters [53]. Such ordinances:

- Apply only to the developments specified,
- Create affordable units for families with a certain percentage or less of area median income, and
- Ensure affordable units stay affordable for a specified time period, which usually differs for rental and sale units.

An inclusionary ordinance mandates that the developers must set aside a certain percentage of units in the new residential developments as affordable, in exchange for government incentives such as density bonus, impact fee waiver, streamline permitting and relaxing regulations [54][55]. In exceptional cases, developers may provide land, money, or affordable housing off-site. The government incentives, predetermined parameters, and exemptions under the inclusionary zoning ordinance vary among cities, as well as among neighbourhoods. The most commonly adopted development incentives are highlighted below.

Density bonus: This permits developers to construct additional units than the local zoning regulations typically allow, and enables them to create more housing units without having to purchase additional land. This "free land" acts as subsidy in the rent or sale price of affordable units. Montgomery County, Maryland, USA best exemplifies this. In Maryland, in all developments with more than 50 units, developers must set aside 12.5 to 15 % of the units as affordable housing, in exchange for a density bonus of up to 22 % [54].

Density bonus is also being adopted—by cities—as an innovative financial tool to raise funds for transit infrastructure [56]. In such cases, the transit agencies and housing authorities negotiate—with each other—before framing the inclusionary zoning policy, to ensure that a certain percentage of funds raised through density bonus is committed towards the provision of affordable housing in TODs.

Impact fee waiver: This incentive waives/reduces/defers the traditional one-time charge—applicable to developers—for the cost of adding additional public services to the new development. Boulder County, Colorado, USA best exemplifies this. The developers here must provide 20 % of the total units as affordable housing, in exchange for impact fee waiver [54]. This tool might be feasible in developed countries, where adequate funds are available for social infrastructure. However, it might not be economically viable in developing countries where funds are sparse. Stakeholders take a call on implementing this tool based on the availability of funds.

Streamline permitting: This program operates on the 'time is money' principle in developing housing. It entitles affordable housing projects to expedite review by the local government.[57]. Austin, Texas, USA exemplifies this approach. The city expedited the permit reviews to affordable housing projects in TODs, under its SMART (Safe, Mixed-Income, Accessible, Reasonably priced, Transit-Oriented) programme. The average completion time for SMART housing reviews was approximately half that of conventional reviews [34]. This tool can be implemented in developing countries as well, as it is

economically viable and does not involve cost to the authorities. It offers a win-win solution for the developers and the authorities.

Parking management measures: Parking space per dwelling unit is one of the key factors in determining the housing budget. Since affordable units require fewer parking spots—especially if they are located in TODs—relaxing parking standards, and unbundling parking cost from dwelling cost, can effectively incentivise reducing the cost of affordable housing[58]. Portland, Oregon, USA exemplifies the introduction of maximum rather than minimum parking standards. The maximum parking allotment varies depending on site distance from bus or light rail (closer the transit, lesser the parking allotment) [59]. This tool is financially self-sustainable. However, while implementing it, cities must conduct a detailed parking demand and supply analysis at each TOD. Parking demand differs among TODs, and parking norms suitable to one may be unsuitable to another

b. ***Accessory dwelling unit (ADU):*** An ADU is a small unit added to an existing home either through a basement conversion, or in the backyard or above a garage—or included in a newly constructed home [60][61]. ADUs typically cover 50 to 60 square meter and are affordable for the urban poor. Most of the cities in USA adopt ADUs, especially Washington where more than 20,000 households are willing to provide ADUs to accommodate affordable housing[57]. As most TOD housing is multi-story high-rise housing, this tool is only useful in areas further out but still influenced by TODs. It is an example of a tool with greater application to developed low-density cities than high-density emerging cities like Bengaluru.

2.3.2. Financing

This section includes the tools related to innovative financing methods to help fund affordable housing production in TODs.

a. ***Tax increment financing (TIF):*** TIF funds are generated from the increase in the property-related taxes and/or sales taxes within a specific district. The additional tax money can be generated by both new development, and the enhanced assessed value of existing properties as a result of improvements around them[52]. Beltline in Atlanta, Georgia, USA exemplifies the use of TIF for providing affordable housing. In 2005, a tax allocation district (TAD) was created around 22 miles of historic Beltline, for revitalizing the disinvested areas around new transit. The TAD project includes a wide range of urban redevelopment and accessibility projects. The city allocated 15% of TIF generated in TAD towards an affordable housing fund[62]. This tool can be implemented only in countries where the guided and actual land values are same. It might not be applicable to countries like India where the guided and actual land values vary hugely as the vast difference might make assessing the TIF funds in TODs infeasible.

b. ***TOD targeted housing funds:*** The various departments, which are responsible for providing affordable housing can access various funds controlled by national, state and local authorities. Each of these funds include corresponding funding qualifications that can be adjusted or targeted to assist affordable housing development in TODs. This tool is economically viable, as the authorities need not spend extra towards providing affordable housing in TODs. It offers a win-win solution for the authorities and the affordable housing beneficiaries

c. ***Land banking:*** A land bank is a governmental entity created exclusively to acquire, hold and facilitate development on vacant, abandoned brownfield properties. Land banks typically assert their own legislation, to enable transfer of land to private developers (for

profit or not-for profit) with certain conditions on how the property will be developed. Bogota, Colombia exemplifies this tool's implementation. The city acquires agricultural land close to the proposed bus rapid transit system at relatively cheap prices (before the bus proposals are made public), converts it to residential land, and provides public utilities. The property is sold to developers at higher prices to help cover infrastructure costs, along with the rider that average prices be kept under US$ 8,500 per unit and be affordable for families with income less than US$ 200 per month [63]. This tool not only facilitates incorporating affordable housing in TODs, but also serves as an innovative financial tool to fund transit infrastructure, as in Hong Kong and Singapore. However, the tool might not be applicable in the strong real estate market, where land price is high, or no land is available for acquisition.

2.3.3. Joint development programs in TODs

Joint development programmes enable developments with the government, community and private developers working in coordination. This section highlights the tools, which facilitate joint development programmes, along with their best practices.

a. ***Public private partnership (PPP):*** PPP's enable the sharing of resources to produce public benefit projects. Shared resources may include land, financing, knowledge or another valuable component of the development process. There is a range of ways that the public agencies can facilitate the building of rail and TODs, for example, public agencies can provide the land or assemble it, and private agencies can provide the financing for development on the land. This is how TODs are built in Japan and Hong Kong who use PPP's to fund transit infrastructure and public housing. Transit agencies in Hong Kong sell the development rights of areas above (air rights) and adjacent to the station areas to the highest bidder, and negotiate a share of future property development or a co-ownership position. In 2009, these active real estate activities by the transit agency contributed to 62% of the transit revenue and 40% of housing stock in station areas [28]. This tool works primarily when the government owns the land near TODs. For instance, in Hong Kong, while implementing this tool, cities must ensure distribution of benefits towards financing transit infrastructure as well as towards social goals.
b. ***Joint developments:*** Joint development allows sharing of the property interests held by the transit agency with private entities or other government entities. Bay Area Rapid Transit (BART), California, USA exemplifies the adoption of joint development. The Unity Council, a local community development corporation (near Fruitvale BART station, located south of downtown Oakland) and BART agreed to a land swap. It enabled the Unity Council to develop TODs including affordable housing on BART's property. In exchange, the Unity Council provided a garage for BART at a location away from transit [34]. As with PPPs, this tool can be adopted only if the land near the transit stations is government-owned.
c. ***Development agreements:*** Development agreements are contracts between local governments and developers that assure long-term planning approvals for a project for a certain number of years (applicable even if zoning policies change later), in exchange for specific public benefits from the developer. Affordable housing may be one of these benefits. Portland, USA successfully exercised this during the development of the River District Urban Renewal Area, which includes the transit-rich Pearl District. In 1994, the Portland Development Commission (PDC) entered into a development agreement with the master developer, to build nearly 7,500 units with the following housing target goals:

33% upper income, 20% middle income, 20% moderate income, 13% low income, and 14% extremely low income [34]. The Pearl District redevelopment around the new tram has been seen as a big success for Portland and a model for America [1]. This is another example of an innovative tool which does not impose any financial burden on government entities to develop affordable housing in TODs. However, its applicability in a TOD depends on the legislation governing the particular TOD.

d. ***Community benefit agreements (CBAs):*** A CBA is a contract negotiated between community groups and a prospective developer, in which the developer agrees to provide particular community benefits—related to the project—in exchange for the community's support. This tool is useful in cases where community acceptance is critical to the project's success. The Staples Center CBA, created in Los Angeles, USA in 2001, is widely considered the ideal CBA. Initially, the project encountered significant opposition from community groups concerned about its impact on surrounding low-income communities. Ultimately, community members and the developer signed a contract in which the developer agreed to modify the project to include affordable housing and other amenities. In exchange, the community coalition extended union support for the expansion, which expedited the city council approval of the project [7]. This tool offers an economically viable solution to incorporate affordable housing and other social infrastructure in TODs. However, it works well only if community support plays a vital role in the success of a new project's implementation.

As is evident from the literature review (above), there are various tools for inclusive TODs. Planners and stakeholders must identify the economically sustainable tools applicable to their region, either existing or a new set of tools. Towards improving the odds of implementation of these tools, in contrast to conventional planning, the study intends to involve all the stakeholders involved in TOD planning to identify affordable housing strategies in their regions. To enable this, the study proposes a three level stakeholder deliberation based on community engagement literature. The proposed stakeholder deliberation framework is described in detail in the next section.

3. Stakeholder Deliberation Process Framework to Identify Affordable Housing Strategies in TODs

The deliberation process facilitates engagement or interaction among the stakeholders. It provides them an opportunity to find out more about a topic, consider relevant evidence and discuss it with other participants before presenting their views. This can happen over a few hours or months. According to the International Association for Public Participation (IAP2), engaging the community or stakeholders in decision making involves five levels, from planning to implementation: inform, consult, involve, collaborate and empower [64]. Inform is a one way commination—providing information to the participants. Consult is a two way communication, designed to take feedback on proposals, alternatives for final decision making. Involve is designed to identify issues and concerns. Collaborate is designed to develop solutions for the identified issues. Empower is providing resources to the community to implement solutions. Engaging community and stakeholders, at various levels, is being adopted successfully by various countries, for sustainable and democratic decision making.

The study intend to adopt this process towards identifying affordable housing strategies in collaboration with the stakeholders. To facilitate this the study proposes stakeholder deliberation in three levels, including inform, involve and collaborate. The other two levels, consult and

empower, are relevant during the implementation of the identified strategies. The tasks under the three levels—in the proposed stakeholder deliberation framework—are described in **Figure 6**.

The first level in the framework involves informing stakeholders about existing policies and their implementation, neighbourhood characteristics, existing inclusive housing strategies and case cities to guide them in identifying the potential local strategies. The second level constitutes involving the stakeholders in identifying the issues affecting the implementation of the affordable housing policies in TODs. The last level is collaborating with the stakeholders to identify strategies suited to the local context, to address the issues identified at the previous level.

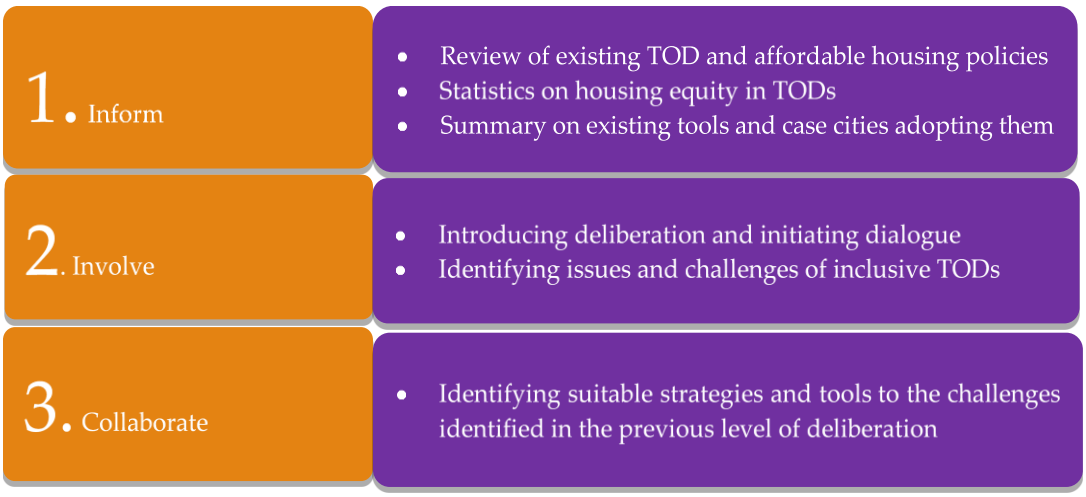

Figure 6. Stakeholder deliberation process framework to develop affordable housing strategies in TODs.

3.1. Informing Stakeholders

The International Association for Public Participation (IAP2) defines 'inform' as a one-way communication providing balanced and objective information to assist the stakeholders in understanding problems, alternatives and/or solutions [65]. At the first level of the proposed stakeholder deliberation framework, planners must provide the information about existing policies, case study area characteristics, and existing strategies. It provides a realistic picture to the stakeholders about the TOD characteristics and its performance as well as an insight to the strategies adopted by developed countries. This information will guide the stakeholders in discussing, querying and drawing conclusions in subsequent levels of the deliberation. This information helps mitigate the stakeholders' own perceptions and assumptions, and develops a common understanding, towards better decision-making. The detailed description of the information which needs to be provide to the stakeholder is given below.

3.1.1. Existing TOD and Housing Policies Relevant to the Case Study Area

This involves reviewing all TOD and housing policies applicable to the case study area, summarizing the information, and presenting it to the stakeholders.

3.1.2. Statistics on Housing Equity in TODs

To provide statistics on housing equity in TODs, the planners must collect extensive primary and secondary data—within the case study area—including socio-economic, housing,

transportation, and land use characteristics. Based on this data, they must evaluate the following parameters:

- Housing affordability of TODs for various income groups - using a housing affordability index;
- Gentrification issues in TODs - by examining the change in the neighbourhood's socio-economic profile, or by comparing the socio-economic profile of new residents with that of old residents;
- The change in land use characteristics of the case study area (land use before implementation of the transit plans vs. current land use); and
- Impact of gentrification issues on transit ridership - this is an important economic consideration for transit authorities.

3.1.3. Briefing of Existing Tools to mitigate gentrification in TODs and case cities adopting them

The summary of all the existing tools and case cities adopting them, as highlighted in the literature review above, must be presented to the stakeholders at the start of the deliberation.

3.2. Involving Stakeholders in Identifying Challenges

According to IAP2, the term 'involve' is defined as a participatory process designed to help identify issues and views, to ensure that the stakeholders' concerns and aspirations are understood and considered before arriving at a decision [65]. As the study endeavours to identify the issues/concerns in incorporating affordable housing in TODs, it proposes the following question for initiating the stakeholder deliberation:

What are the challenges in implementing affordable housing in TODs?

3.3. Collaborating with Stakeholders towards Identifying Solutions

According to the IAP2, the term 'collaborate' is defined as working together towards exploring alternatives and identifying preferred solutions to the challenges identified in the previous level of deliberation [65]. Stakeholders must consider all the information provided before proposing strategies, as each neighbourhood is unique and merits specific solutions to deal with affordable housing challenges. After the deliberation, the facilitators must map the challenges with the respective strategies and tools—in order of priority—and share the deliberations' results with the stakeholders for their feedback.

The stakeholder deliberation process presented above bring out co-intelligence and wisdom in governance [35]. They effect a sense of ownership and responsibility to take the recommendation forward. The proposed stakeholder deliberation framework can be applied to any TOD context towards identifying affordable housing strategies. However, prior to illustrate this framework, planner needs to do extensive background work to provide the necessary information highlighted above to the stakeholders. The developed countries are likely to maintain data on the housing, socio-economic, land use and transportation characteristics, thus making the data readily available to provide information to the stakeholders. However, developing countries like India lack proper data management systems. Often the researchers must gather the data from various primary and secondary sources.

To illustrate the value of the deliberation process towards identifying the affordable housing strategies and the methodology to facilitate the deliberation framework, it is administrated to Yeshwanthpur industrial area.

4. Applying the Stakeholder Deliberation Framework in the Case Study Area: Yeshwanthpur Industrial Area, Bengaluru

This section describes the case study area, the methodology to facilitate the proposed stakeholder deliberation, and the administration of the stakeholder deliberation framework within the case study area.

4.1 Case study area:

Bengaluru is the fourth most populous city in India, with a population of around 8.5 million. The city is on its way to providing its citizens a metro transit system, with a total estimated budget of 400 billion INR. Currently, a 32 km stretch is operational and an 83 km stretch is under construction [66]. To increase transit ridership and generate revenue, the city administration is not only investing in transit infrastructure but also facilitating TODs. In the interest of TOD implementation, the areas within 500m from the metro stations are allowed a floor area ratio (FAR) of four—for all permissible uses—irrespective of the applicable limit (generally varies from 1.7 to 2.4 depending on the land use) [67]. The generous public transit infrastructure investments along with the zoning incentives are attracting large-scale capital investments towards TODs. Thus it is not unexpected that the station areas are witnessing dense new high-rise structures [8].

In Bengaluru, the Yeshwanthpur industrial area was selected as a case study area to apply the proposed stakeholder deliberation framework. The metro has been operational here since 2013. This area exhibits the features of a working class, industrial, suburban neighbourhood, with a traditional housing area on one side of the metro station, and a vacant brownfield site and industries on the other (Figure 7). The brownfield side has seen the construction of a large number of high-rise luxury condominiums on the vacant and abandoned industrial areas adjoining the metro station. As of 2015, these condominiums accounted for 1000 new households in the area. Additionally, two high-rise structures were under construction, and many others were under planning or potentially to be built due to the availability of land. On the other side in the traditional housing area, there were few signs of redevelopment yet, but this could gain momentum once the easily available brownfields sites are developed. The Yeshwanthpur industrial area is ideal for applying the proposed stakeholder deliberation framework, given that the scope of further developments provides the stakeholders an opportunity to implement the identified affordable housing strategies in TODs.

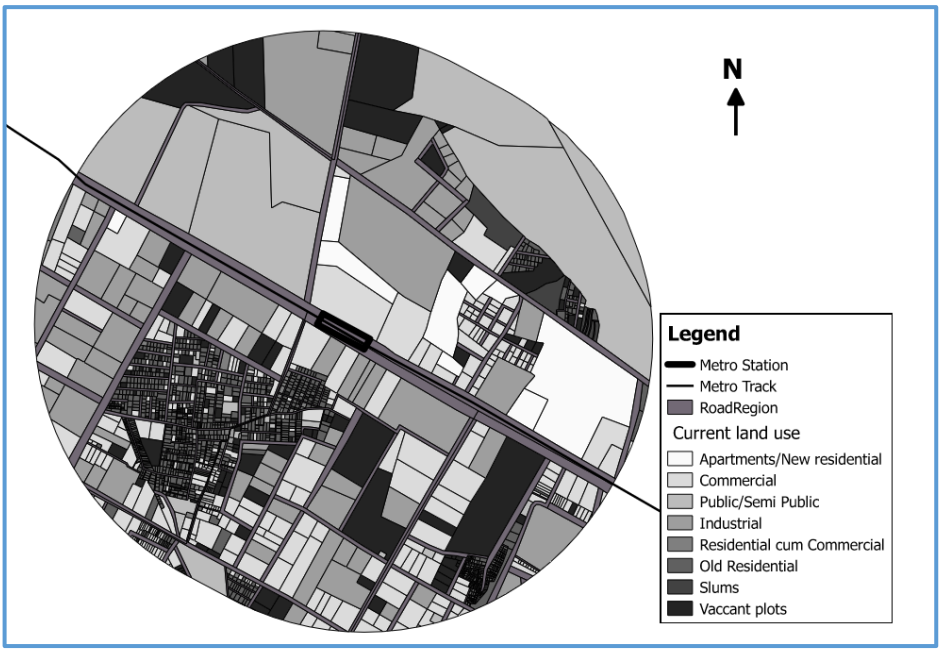

Figure 7. Boundaries and land use characteristics of Yeshwanthpur industrial area, Bengaluru; Source: Indigo Consultancy, Bengaluru.

4.2 methodology to facilitate stakeholder deliberation:

This sub-section discusses the selection of participants for deliberation and the deliberation technique adopted to facilitates stakeholder dialogue and analysis of stakeholder's inputs

4.2.1. Selecting the participants:

To select the participants, firstly we prepared a list of all the organizations involved in TOD planning and decision making. The organization list includes public and private entities, consultants, NGOs, academicians, practitioners, politicians, and other think tanks. Invitations were sent to these organizations. They are proactively appointed representatives to be a part of the deliberation. In some cases, the organization chairperson personally attended the deliberation and provided their valuable inputs. In addition, to involve the community in the deliberation, pamphlets were distributed— door to door—in the case study area. Community members also actively participated in the deliberation. The deliberation involved about 80 participants from a wide range of organizations, including community participants. No random 'citizens for the day' were selected, though in future deliberations such a technique could be used, as the role of neutral citizens is undoubtedly valuable if the issues are gravely contentious [68][69].

4.2.2. Deliberation technique adopted to facilitate stakeholder deliberation

The practice of deliberative democracy is facilitated through various techniques that assist people with disparate viewpoints in seeking common ground and aligning priorities [64][69]. Planners can select any deliberation technique to implement the proposed deliberation process, depending on the availability of resources, and the time frame. Few such examples are

(1) ***World Café:*** This technique brings people together to dialogue on complex issues that are important to a large community. The technique facilitates progressive rounds of conversation. In this process 4 to 5 participants sit at a small table to begin the conversation. After the initial

round one person remains at the table as the host and others move around to other tables to continue the conversation with other hosts. Hosts share the previous group ideas and encourage them to link and connect their ideas with the previous groups ideas.

(2) ***Open Space Technology:*** This technique provides people with a setting and time to dialogue on any issue that is both clear and compelling to the participants. A facilitator provides the context and a few participants take a lead, setting the dialogue's agenda by stating topics relevant to the context. The rest of the participants decide which topic they want to discuss, and join the group with that topic and start the discussion.

(3) ***21st Century Town Meeting/Dialogue:*** In this process, small groups of stakeholders and deliberation-facilitation teams are connected through networked computer software, which helps facilitators quickly summarize participants' inputs, find common ground, and prioritize on-board and complex issues.

(4) ***Consensus forum:*** This method enables deliberation among a large group—comprising stakeholders from the community, industry and government—towards finding common ground on technically complex and often combative issues, and eliciting ownership of an agreed way forward. The forum organizes small group deliberations followed by an extensive plenary session.

All the techniques emphasized above are well established and tested on the ground. Planners can choose any of these to implement the proposed framework, depending on the availability of various resources (space, time, manpower, computers and software), and the stakeholders' willingness.

The current study adopted 21st century dialogue. This technique was preferred because, unlike other methods, it has the ability to reflect the collective view of all the stakeholders in a short span of time [70]. This advanced technique uses networked computers to collect and analyze the stakeholders' inputs [69]. Further, it enables display of results in real time for cross verification, and minimizes any possible manual errors in data collection and analysis.

In the 21st century dialogue, deliberation is facilitated through small-group dialogue between diverse participants. Hence, all the 80 participants are divided into 8 small groups. To ensure diversity in each group, the stakeholders were purposely seated at a table with dissimilar others, that is, a mixture of random sample participants from different organizations. Each group was supported by a trained facilitator, with the task of providing chance to everyone to speak and to ensure that deliberation remain focused on the topic, with minimal digressions. A trained scribe at each group submitted ideas to a computer that the group considered to be a fair representation of their discussion. The ideas fed into the computer were not only commonly-held views, they included minority views, and in many instances, each person's views [70].

The computers on each table were networked, transmitting the data to a 'theme team' who analyzed the data in real time and broadcast the common themes back to the entire room via large screens. To analyze the qualitative data from small groups, the theme team adopted the content analysis. It involves reading the input data from small groups, making a list of different types of information, categorization of the information and identification of categorization that are somehow linked to each other (common theme). Once the common themes were identified, the themes were prioritized, with each participant nominating their individual preferences.

There were over 25 volunteers supporting this deliberation - facilitating, acting as scribes and theme team members. This team was acquired from Curtin University Sustainability Policy Institute (CUSP), Directorate of Urban Land Transport (DULT) and Center for infrastructure, Sustainable Transportation and Urban Planning (CiSTUP). The scribes and facilitators were trained half day by community engagement expert professor. Janette Hartz-Karp to ensure that

they were capable of carrying out their tasks without any interference with the stakeholder input. Theme team was also trained in content analysis to find common themes based on small group inputs.

The morning session in the deliberation focused on the first two levels of engagement viz. inform and involve. The afternoon session focused on stakeholder collaboration to develop solutions.

4.3 Administrating the stakeholder framework in the case study area:

4.3.1 Step 1: Informing Stakeholders

Informed dialogue is the first level of the deliberation. The necessary background information comprised of two well-researched working papers on gentrification issues and their implications on transit ridership in the case study area [8][71]; the housing and TOD policies applicable to the case study area; and the existing tools along with the case studies that adopted them. This information was shared with the stakeholders via presentations. Further, Professor Janette Hartz-Karp briefed the stakeholders regarding the deliberation methodology. The summary of the information shared is presented below.

a. Existing TOD and Housing Policies Relevant to the Case Study Area:

The existing TOD policy applicable in the case study area is that of increasing density to four for all permissible uses within 500 m of a transit station. In exchange of high FAR, the government is imposing a tax of 10% guided value for residential building and 20% guided value for commercial building. The collected fund are shared among BMRCL, Bruhat Bengaluru Mahanagara Palike (BBMP), Bangalore Water Supply and Sewage Board (BWSSB) and Bangalore Development Authority in the ratio of 60%, 20%, 10% and 10%. Unfortunately, the revenue generated in not shared with any housing organization to incorporate affordable housing in TODs [56].

Amongst the existing housing policies, two are relevant to the case study area, viz. the National Urban Housing and Habitat Policy (NUHHP) and the Karnataka Housing and Habitat Policy (KHHP) at the national and state levels respectively. The core focus of these two housing policies is 'Affordable Housing For All'. The NUHHP recommends provision of 10 to 15 % of land in every new public/private housing project or 20 to 25 % of FAR or Floor Space Index (FSI) (whichever is greater), for Economically Weaker Section (EWS)/Low income Group (LIG) housing through appropriate legal stipulations and spatial incentives [72].

To realize the NUHHP's goals, the state government developed the KHHP. The KHHP promotes PPP's and recommends retaining the government as a facilitator. Their most common beneficiaries include members of the EWS (less than ₹3300 per month income) and LIG (₹3300 to ₹7300 per month income) categories. The policy recommended various land, finance, legal, regulatory and rent reforms towards increasing the supply of affordable housing in Karnataka as envisaged in the NUHHP [73].

b. Providing Statistics on Housing Equity in TODs:

During the deliberation, the two working papers (mentioned above) provided the necessary background information on the case study area's housing characteristics. This information is summarized below.

I. *Housing affordability of TODs for various income groups:* To assess the affordability of TOD housing, secondary data on new developments initiate after TOD policy (2009 -2015) was collected from LJ hooker. The housing price of these new developments and the income groups who can own them (derived from housing affordability index) were mapped. The

data analysis indicates that the price of new TOD housing starts at ₹2.5 million, and that majority of the TOD units are priced in the range of ₹5 to ₹7.5 million. The affordability mapping (mentioned above) indicates that a house close to transit cannot be owned at an annual income less than ₹0.6m (assuming affordability index of 4), which is significantly higher than Bengaluru's average annual income, ₹0.15 million [74]. Additionally, the analysis indicates that the price of the developments close to transit nodes is 68% higher than that of the housing located in peripheral areas [8].

II. *Gentrification issues in the case study area*: To provide the implications of new TOD policy on gentrification in Yeshwanthpur Industrial area a detailed household survey was conducted. Based on these data, the socio economic profile of new TOD residents and old TOD residents were compared. The analysis demonstrates that the new developments in TODs attracted only the professional and high-income groups, while completely excluding the poor. However, the old build traditional areas are not being gentrified yet, due to difficulty in amalgamation of small plots [8].

III. *The change in land use characteristics of the case study area:* To illustrate the opportunities for further developments/ susceptibility to future gentrification, secondary data on land use characteristics before and after new TOD developments was collected and change in land use characteristics was analyzed. The results demonstrates that, there is a lot of scope for further developments due availability of large vacant and abandoned brownfield sites. In a do-nothing scenario, they will yield high-end structures—excluding the poor—and that the price shadowing resulting from gentrification might displace the residents of the old residential area once development on the easy brownfields sites is completed [8].

IV. *Impact of gentrification issues on transit ridership:* Gentrification not only triggers equity issues, but can also influence transit ridership. To analyze this the data on HH survey was adopted. In addition to this a metro user survey was conducted. Using this data, influence of gentrification indicators on transit ridership and the metro influence on TOD residents travel behavior analyzed. The analysis results indicates that, though the gentrifiers contribute significantly towards transit ridership, the probability of their using transit and non-motorized transport is lower than that of the non-gentrifiers, who lack access to privately owned motorized vehicles; however in terms of overall transport it is more complex as the roads will have fewer cars and motorbikes if the wealthy use the train [71].

Overall, the data analysis of these two working papers illustrates the housing inequities in TODs at the city level and in the case study area. It indicates that the housing policies have not been implemented, and there are effectively no housing options for EWS and LIG categories among the new developments, especially in TODs. To identify the issues and concerns with respect to implementing the housing policy specifically in the case study area, a stakeholder deliberation was conducted. The next section presents the deliberation's results.

c. Briefing of Existing Tools to mitigate gentrification in TODs and cities adopting them

4.3.2. Step 2: Involving Stakeholders in Identifying Challenges

The 21st century dialogue—during the stakeholder deliberation—aimed at identifying the major issues/challenges in incorporating affordable housing in the case study area. The stakeholders—organized into small groups—identified various challenges. Scribes working with each of the small groups entered the data into computers. The theme team analyzed the small groups' input data and identified five common themes as challenges. These five major challenges and the small groups' inputs regarding each challenge are summarized in the results section.

4.3.3 Step 3: Collaborating with Stakeholders towards Identifying Solutions

Once the stakeholders had identified the challenges, in the afternoon session they deliberated upon each of them to determine their individual solution(s), based on the information presented at the beginning of the deliberation. The solutions and challenges are mapped. The major solutions and discussion around each identified solution are presented in the results section.

5. Results:

The results—the challenges and solutions identified—from the stakeholder deliberation for the case study area were mapped as shown in **Figure 8**. The discussion around each identified challenge and the solution are described below.

Figure 8. Mapping affordable housing challenges with suitable solutions/strategies.

5.1. Challenges in implementing affordable housing in TODs:

During the second level of the deliberation, the stakeholders identified various challenges in incorporating affordable housing in TODs in the case study area. These challenges in order of priority, along with the stakeholder discussions around each identified challenge, are summarized below.

5.1.1. Lack of Collaboration, Coordination and Capacity between and within Agencies; and Conflicting Interests

Inclusive and equitable TOD planning involves various public and private organizations, and the local community. The government organizations often pursue different goals, not working in tandem with others. For instance in Bengaluru, various government organizations cater to affordable housing needs, with varied un-integrated goals (Bengaluru Housing Department, 2009). Moreover, as the authorities involved in the construction of affordable

housing are not involved in the implementation of transit (domain of the transportation authorities), they often do not know about the transit plans until they are made public. By then, the land for construction becomes dearer and can no longer be acquired using any authority's individual funds. In case a government agency owns the land in the station premises, it is reluctant to transfer such a valuable asset (land), to the authority that is looking to acquire it for constructing affordable housing. Such agencies prefer to develop the property for their own organization's profits. The stakeholders expressed concern that the lack of collaboration and cooperation between agencies is a potential obstacle in implementing affordable housing policies in TODs.

5.1.2. Poor Community Engagement

According to stakeholders, the community has little or no say regarding development plans in the neighbourhood, and even less in new developments. By requesting that the community's views be heard before the development plans' approval, the policies and regulations can empower the community to negotiate with the developers and the government regarding the allocation of affordable housing—and other social infrastructure—to improve the quality of life in the neighbourhood.

5.1.3. Lack of Government Ownership of Land

The stakeholders identified the lack of ownership of land close to transit as one of the major constraints in developing affordable housing in the case study area. The majority of the vacant land holdings in this area are owned by private developers and all new TOD housing has been developed by them. The government and the community have less control over these developments. To realise the potential of yielding good revenue, the private developers actively negotiate with the landowners to acquire the land near the station area and thus governments lose power if they do not share some land. However, private owners must still get approval and thus all the mechanisms that involve PPP's and regulations for affordable housing (outlined above) can still be applied. Yet, the participants preferred to use some government land ownership as a major way to control housing markets.

5.1.4. Lack of Political Support and Commitment, and Conflicting Political Interest

The stakeholders felt that lack of funding is one of the main reasons why politicians do not actively pursue affordable housing in TODs. Additionally, aggressive lobbying by the developers is a hindrance in politicians' encouraging of inclusionary zoning.

5.1.5. Inadequate Policies and Regulations

The existing legislations—merely a couple of policies—for affordable housing were found inadequate by the stakeholders. Participants suggested various essential instruments for providing affordable housing were lacking: no regulations for mandatory imposition of the provision for affordable housing, no policy for defining the role of each agency in implementing and monitoring the provision of affordable housing in TODs, no land banking entity to facilitate land banking in TODs, and no legislation for promoting smooth transfer of land rights to appropriate housing authorities or private developers.

5.2 Strategies to implement affordabile housing in TODs:

During the third level of the deliberation, the stakeholders identified strategies towards combating each of the identified challenges. These strategies are summarized below.

5.2.1 Inclusionary zoning:

In the case study area, the government owns neither any vacant land for developing affordable housing nor the funds to acquire highly priced land. To overcome this hurdle in incorporating affordable housing in new TODs, the stakeholders suggested that inclusionary zoning be mandated through regulations. A majority of them recommended high FAR/density bonus as incentives to the developers, in exchange for affordable housing. Rather, these are being used as innovative financial tools to raise funds to invest on transit and other necessary social infrastructure, and these funds are distributed among BMRCL, BWSSB, BDA and BBMP. However, the stakeholders felt that a certain amount of money needs to be allocated to fund affordable housing. Additionally, a minority amongst the stakeholders suggested relaxing parking norms as an incentive. But the others felt that parking norms in Indian cities are already lenient and that further relaxation may amount to illegal street parking.

The rest of the tools under inclusionary zoning did not receive significant attention.

5.2.2 Special purpose vehicle (SPV):

The deliberations established that setting up an SPV for station area level plans can address the lack of collaboration and coordination between and within agencies. SPV's have been set up in other areas of government but not for TODs. It can bring all the stakeholders under one umbrella and protect each organisation's goals, without compromising the community's wellbeing. It can facilitate engagement between government entities, developers and communities, with the objective of equitable and sustainable TODs. These engagements can establish development agreements, community benefit agreements, PPP models, and other joint development plans. The SPV can also act as a real estate agency to negotiate with private developers and community coalitions, on future developments in exchange for government incentives.

5.2.3 Community benefit agreement (CBA):

The stakeholders felt that CBAs can facilitate community involvement at the planning stage. For the CBAs to be effective, the stakeholders suggested that the community's approval be mandated for the approval of any new development in the TOD neighbourhood. CBAs can help maintain the essence of the community, foster the community's sense of ownership of their neighbourhood, and mitigate any resistance from them, during the implementation of the projects.

5.2.4 Station area level planning:

According to stakeholders, developing station area level or local area level plans in collaboration with the community is the best way for cities to ensure equity and sustainability in TODs. It helps in identifying the opportunities and challenges at a local level, and generating solutions that are applicable in the local context rather than adopting blanket recommendations throughout the city. Hence, the stakeholders recommended preparing station area level plans along with the transit corridor level plans, to incorporate affordable housing in TODs.

5.2.5 Innovative financing mechanism:

The cities' paucity of funds to invest in public facilities has fuelled innovative thinking about financing mechanisms. Identifying innovative ways to finance transit and TOD projects helps eliminate reliance on government funds, and leverage the politician's willingness. The

stakeholders recommended that the various housing programmes that are already in place must be implemented in TODs. The prominent housing programmes in Bengaluru include: Urban Ashraya Housing Scheme (housing financial assistance and loans for EWS), Urban Ashraya Sites Scheme (free sites for EWS), Dr. Ambedkar Housing Scheme (free housing—without loan component—for the socially and economically weaker scheduled castes and scheduled tribes), and Hundred Housing Projects (providing 15,000 sites and 13,500 houses, at an approximate cost of Rs. 850 Crores). The funds dedicated to these housing programmes can be directed towards affordable housing in TODs.

The stakeholders did not favour TIF as an innovative financing tool in India. They felt that it may not be possible to estimate the increase—induced by transit infrastructure—in tax revenue, given the lack of transparency in India's taxation system and the wide gap between guided and actual land values. Instead, the stakeholders favoured land banking as a financial tool for the proposed commuter rail, which is currently under planning. Most of the land around the commuter rail in the suburbs is under agricultural use. The stakeholders suggested that the government should act now to acquire some of the agricultural land—through a land banking government entity—for the production of housing and other infrastructure in the future. The sale of land or the use of joint development mechanisms can all include affordable housing goals. Acquiring the land sooner—rather than later—will help avoid the anticipated price rise.

5.2.6 Mandated inclusionary zoning:

Developers work with the aim of optimising profits, for which they often lobby politicians for exemption from any regulation, which can lower the profit margin. To check such lobbying by developers, the stakeholders recommended mandatory imposition of the inclusionary zoning ordinance in all new developments, without the scope for exemptions.

5.2.7 Inadequate regulations, policies and legislations:

The various strategies proposed to address this gap include mandatory inclusionary zoning in exchange for density bonus and parking relaxations, SPVs and a land banking entity with special legislative power to transfer land to private developers and government organisations for developing affordable housing, and policies to define the responsibility of each agency in incorporating affordable housing in TODs.

6. Discussion

In the process of deliberation, the stakeholders shared their concerns and views—with one another—for the inclusion of affordable housing in TODs. Many new and existing set of tools were identified during this deliberation, to make affordable housing a reality in the case study area.

In the category of tools related to zoning regulations, local codes, fees and procedures, inclusionary zoning was identified as an important financially viable tool to implement in the case study area. Under inclusionary zoning, density bonus and relaxing parking norms were preferred as incentives for the developers. The stakeholders did not favor impact fee waiver, as Bengaluru is already faced with paucity in funds to invest on public infrastructure. Surprisingly, the stakeholders did not suggest streamline permitting, although it does not incur any costs to them. ADUs did not find any favor, as in Bengaluru, especially in the case study area, the plots are small and might not lend themselves to accommodating an additional small unit.

In the category of tools related to financing, the stakeholders did not support the idea of TIF, due to the lack of a transparent property tax assessment system in Indian cities. TOD targeted

housing funds was identified as a preferred solution in the strong real estate market in the case study area. Land banking was identified as a tool to be adopted in emerging and weak real estate market areas, and in future transit and TOD plans.

Under the category of joint development programs in TODs, only CBAs were preferred as an economically sustainable solution. The stakeholders did not favor PPPs, joint developments, and development agreements, as they can be implemented only if the government owns land in the station premises. Unfortunately, in the case study area, the government does not own any large vacant plots. However, the stakeholders felt that they could use these tools in future transit and TOD plans, to finance transit and social infrastructure, including affordable housing.

In addition to the existing tools for inclusive TOD planning, the stakeholders proposed a set of strategies. Firstly, they proposed setting up an SPV to bring all stakeholders together, to monitor the development of inclusive TODs through the planning to implementation stages. Secondly, they proposed mandating that the station area level planning during planning a transit corridor, must involve collaboration with the stakeholders, for more sustainable and equitable TOD planning

7. Conclusions

A Framework for Stakeholder Deliberation has been outlined which can be applied to any TOD where the inequities are emerging to ensure there are inclusionary housing processes to enable the TOD to be inclusive and thus more fully sustainable. The application to a case study in Bengaluru has shown that the framework can work and provide the kind of options to stakeholders that can create more inclusionary outcomes. This is the first attempt in Bengaluru to bring all the stakeholders (who are involved in TOD planning) on a common platform to dialogue on the equity issues faced by TODs. The response was very positive to the process. The Framework was effective in disseminating the implication of new transit system and its associated developments on equity objectives in the case study area in the form of information to the stakeholders, in identifying issues and finding innovative solutions towards inclusive TODs. The conclusions in the Bengaluru process opened the way for: inclusive housing regulations, setting up SPVs and land banking entities, developing local area plans in collaboration with the community, and finally implementing them. There is a continuing commitment within the political and administrative system to achieving these policy outcomes but they do amount to a long-term process. In this whole process, many more deliberations among all the stakeholders need to be conducted. The proposed deliberation framework can be modified according to the deliberation objectives and extended to other future deliberations as well. With this deliberation, the stakeholders realized the strength of the deliberation technique in shaping inclusive and sustainable TODs, and are committed to implementation.

The proposed deliberation framework creates awareness among policymakers, planners and city authorities, on equity implications in TOD planning. Further, it guides them in developing more equitable and sustainable TODs, especially in the developing world, which is witnessing new transit infrastructure and TODs on a large scale.

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supervised and assisted with manuscript completion, editing and co-authorship of manuscript. The two authors have read and approved the final manuscript.

References

1. Newman, P.; Kenworthy, J. The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning; Island Press: Washington D.C, 2015.

2. Mu, R.; Jong, M. De Establishing the conditions for effective transit-oriented development in China: the case of Dalian. J. Transp. Geogr. 2012, 24, 234–249.

3. Cervero, R.; Kockelman, K. Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon 1997, 2, 199–219.

4. Guerra, E.; Cervero, R.; Tischler, D. The Half-Mile Circle: Does It Best Represent Transit Station Catchments?; Report, Institute of Transportation Studies, University of California, Berkeley, 2011.

5. McIntosh, J.; Turbka, R.; Newman, P. Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. Transp. Res. - Part A 2013, 67, 320–339.

6. Reconnecting America; Center for Community Innovation; Non-Profit Housing Association of Northern California Transit-Oriented for All : The Case for Mixed-Income Transit-Oriented Communities in the Bay Area; Berkeley, CA: Center for Community Innovation, 2007.

7. Feinstein, B. D.; Allen, A. Article Community Benefits Agreements with Transit Agencies : Neighborhood Change Along Boston's Rail Lines and a Legal Strategy for Addressing Gentrification. Transp. law J. 2008, 38, 85–114.

8. Chava, J.; Newman, P.; Tiwari, R. Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore; Curtin University Sustainability Policy Institute, Curtin University, Perth, WA, 2016.

9. Kahn, M. E. Gentrification Trends in New Transit-Oriented Communities : Evidence from 14 Cities That Expanded and Built Rail Transit Systems. Real Estate Econ. 2007, 35, 155–182.

10. Lin, J. Gentrification and Transit in Northwest Chicago. J. Transp. Res. Forum 2002, 56, 175–191.

11. Davidson, M. Gentrification as global habitat: a process of class formation or corporate creation? Trans. Inst. Br. Geogr. 2007, 32, 490–506.

12. Davidson, M.; Lees, L. New-build gentrification and London's riverside renaissance. Environ. Plan. A 2005, 37, 1165–1190.

13. Smith, N. Gentrification and Uneven Development. Econ. Geogr. 1982, 58, 139–155.

14. Ministry of Housing and Urban Poverty Allevation Guidelines for Interest Subsidy Scheme for Housing the Urban Poor (ISHUP); New Delhi, 2009.

15. Ministry of Housing and Urban Poverty Allevation Guidelines for affordable housing in partnership; Government of India, New Delhi, 2009.

16. Ministry of Housing and Urban Poverty Allevation Affordable housing in partnership Scheme guidelines; Government of India, New Delhi, 2013.

17. Housing and Transportation Cost Study; Report, City of Portland Bureau of Planning and Sustainability, Portland., 2009.

18. Cervero, R.; Chapple, K.; Landis, J.; Wachs, M.; Duncan, M.; Scholl, P. L. MAKING DO: How Working Families in Seven U.S. Metropolitan Areas Trade Off Housing Costs and Commuting Times; Washington, DC: Center for Housing Policy, 2006., 2006.

19. Arora, A.; Tiwari, G. A Handbook for Socio-economic Impact Assessment (SEIA) of Future Urban Transport (FUT) Projects; Transportation Research and Injury Prevention Program (TRIPP), Indian Institute of Technology, New Delhi, 2007.

20. He, S. New-Build Gentrification in Central Shanghai: Demographic Changes and Socioeconomic Implications. Popul. Space Place 2010, 361, 345–361.

21. Litman, T. Affordable-Accessible Housing In A Dynamic City Why and How To Increase Affordable Housing Development In Accessible Locations; Report, Victoria Transport Policy Institute, Canada., 2013.

22. Chava, J.; Newman, P.; Tiwari, R. Gentrification of station areas and its impact on transit ridership; Curtin University Sustainability Policy Institute, Curtin University, Perth, WA, 2016.

23. Jillella, S.; Matan, A.; Newman, P. Participatory Sustainability Approach to Value Capture-Based Urban Rail Financing in India through Deliberated Stakeholder Engagement. Sustainability 2015, 7, 8091–8115.

24. Van Gent, W. P. C. Neoliberalization, Housing Institutions and Variegated Gentrification: How the "Third Wave" Broke in Amsterdam. Int. J. Urban Reg. Res. 2013, 37, 503–522.

25. Newman, P.; Kenworthy, J. Sustainability and Cities: Overcoming Automobile Dependence; Island Press, Washington, DC., 1999.

26. Newman, P.; Kenworthy, J. Cities and Automobile Dependence: An International Sourcebook; Gower, Aldershot, UK., 1989.

27. Cervero, R. Transit-based housing in California: evidence on ridership impacts. Transp. Policy 1994, 1, 174–183.

28. Cervero, R.; Murakami, J. Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Stud. 2009, 46, 2019–2043.

29. Cervero, R. Transit Transformations: Private Financing and Sustainable Urbanism in Hong Kong and Tokyo. In Physical Infrastructure Development: Balancing the Growth, Equity and Environmental Imperatives; Ascher, W.; Krupp, C., Eds.; Palgrave Macmillan: New York, 2010; pp. 165–185.

30. Newman, P.; Matan, A. Green Urbanisam in Asia: The Emerging Green Tigers; Ying, L. X., Ed.; World Scientific, 2013.

31. Reconnecting America An Equitable TOD Typology for the Atlanta Region; 2013.

32. Reconnecting America User's Guide TOD Classification Tool; 2014.

33. Newman, P. Density, the Sustainability Multiplier: Some Myths and Truths with Application to Perth, Australia. Sustainability 2014, 6, 6467–6487.

34. Mixed-Income Transit-Oriented Development www.mitod.org (accessed May 31, 2015).

35. Hartz-karp, J. How and Why Deliberative Democracy Enables Co-Intelligence and Brings Wisdom to Governance How and Why Deliberative Democracy Enables Co-Intelligence and. J. Public Delib. 2007, 3.

36. Machell, E.; Reinhalter, T.; Chapple, K. Building Support for Transit-Oriented Development : Do Community-Engagement Toolkits Work ?; Berkeley, CA: Center for Community Innovation, 2009.

37. Lierop, D. van; Maat, K.; El-Geneidy, A. Talking TOD : Learning about Transit-Oriented Development in the United States , Canada , and the Netherlands. J. Urban. 2016, 1–31.

38. Nordregio; OIR; TU Delft Transit-oriented development and sustainable urban planning; Report for JPI Urban Europe CASUAL project, 2016.

39. Pojani, D.; Stead, D. A Critical Deconstruction of the Concept of Transit Oriented Development (TOD) Dorina Pojani, Dominic Stead. In Real corp; SCHRENK, M.; V. POPOVICH, V.; ZEILE, P.; ELISEI, P.; BEYER, C., Eds.; 2016; Vol. 2, pp. 829–833.

40. Suzuki, H.; Iuchi, K.; Cervero, R. Transforming cities with transit: Transit and Land-Use Integration for Sustainable Urban Development; World Bank: Washington DC, 2013.

41. Ogra, A.; Ndebele, R. The Role of 6Ds : Density , Diversity , Design , Destination , Distance , and Demand Management in Transit Oriented Development (TOD). Neo-International Conf. Habitable Environ. 2013, 539–546.

42. Cervero, R.; Day, J. Suburbanization and transit-oriented development in China. Transp. Policy 2008, 15, 315–323.

43. National Urban Transport Policy; Report, Directorate of Urban Land Transport, New Delhi., 2001.

44. Rangwala, L.; Mathews, R.; Sridhar, S. Shifting Discourse About Transit-Oriented Development in Mumbai, India. Transp. Res. Rec. J. Transp. Res. Board 2014, 2451, 60–67.

45. Pollack, S.; Bluestone, B.; Billingham, C. Maintaining Diversity In America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change; Dukis Center for Urban and Regional policy, Northeastern University, 2010.

46. Loukaitou-Sideris, A. A New-found Popularity for Transit-oriented Developments? Lessons from Southern California. J. Urban Des. 2010, 15, 49–68.

47. Knaap, G. J.; Ding, C.; Hopkins, L. D. Do Plans Matter?: The Effects of Light Rail Plans on Land Values in Station Areas. J. Plan. Educ. Res. 2001, 21, 32–39.

48. Topalovic, P.; Carter, J.; Topalovic, M.; Krantzberg, G. Light Rail Transit in Hamilton: Health, Environmental and Economic Impact Analysis. Soc. Indic. Res. 2012, 108, 329–350.

49. Yan, S.; Delmelle, E.; Duncan, M. The impact of a new light rail system on single-family property values in Charlotte, North Carolina. J. Transp. Land Use 2012, 5.

50. Chapple, K. Mapping Susceptibility to Gentrification : The Early Warning Toolkit; Berkeley, CA: Center for Community Innovation, 2009.

51. Grube-cavers, A.; Patterson, Z. Urban Rapid Rail Transit and Gentrification in Canadian Urban Centres – A Survival Analysis Approach. Urban Stud. 2015, 50.

52. Shoemaker, D. Tools for Mixed-Income TOD; Report for Center for Transit Oriented Development, 2006.

53. Brown, K. D. Expanding Affordable Housing Through Inclusionary Zoning : Lessons from the Washington Metropolitan Area; The Brookings Institution Center on Urban and Metropolitan Policy, Washington, DC., 2001.

54. Benson, N. A Tale of Two Cities: Examining the Success of Inclusionary Zoning Ordinances in Montgomery County, Maryland and Boulder, Colorado. J. Gender, Race Justice 2010, 13, 753–777.

55. Calavita, N.; Grimes, K.; Mallach, A. Inclusionary housing in California and New Jersey: A comparative analysis. Hous. Policy Debate 1997, 8, 109–142.

56. Ministry of Urban Development Innovative financing of Metro Rail Projects; Government of India, 2012.

57. Nelson, A. C. Top Ten State and Local Strategies to Increase Affordable Housing Supply. Hous. Facts Find. 2003, 5.

58. Parking Spaces / Community Places: Finding the Balance through Smart Growth Solutions; Report, EPA's Development, Community, and Environment Division, U.S. Environmental Protection Agency, Washington, DC., 2006.

59. Weinberger, R.; Kaehny, J.; Rufo, M. U.S. Parking Policies : An Overview of Management Strategies; Report, Institute for Transportation and Development Policy, New York., 2010.

60. Chapple, K.; Wegmann, J.; Nemirow, A.; Dentel-Post, C. Yes in My Backyard: Mobilizing the Market for Secondary Units; Berkeley, CA: Center for Community Innovation, 2012.

61. Nemirow, A.; Chapple, K. Yes , But Will They Let Us Build ? The Feasibility of Secondary Units in the East Bay; IURD Working Paper, Berkeley, CA: Institute of Urban & Regional Development, 2012.

62. The city of Atlanta Beltline Tax Allocation District Ordinance; 05-O-1733, Georgia., 2005.

63. Cervero, R. State Roles in Providing Affordable Mass Transport Services for Low - Income Residents. In International Transportation Forum; 25- 27 May, Leipzig, Germany, 2011.

64. Government of South Australia Community Engagement Handbook: A Model Framework for leading practice In Local Government in South Australia; 2015.

65. International Association for Public Participation www.iap2.org.au (accessed Apr 25, 2016).

66. Bangalore Metropolitan Rail Corporation Limited www.bmrc.co.in.

67. Government of Karnataka Amendment to the zoning regulations of master plan of Bangalore; UDD 93 MNJ 2008, India., 2009.

68. Hartz-Karp, J., Newman, P. (2006) The Participative Route to Sustainability. In Communities Doing it for Themselves: Creating Space for Sustainability; Paulin, S., Ed.; University of Western Australia Press, Perth., 2006.

69. Hartz-Karp, J.; Gollagher, M.; Weymouth, R. Sustainability through deliberative Democracy; Workbook, Curtin University Sustainability Policy Institute, Perth, 2013.

70. Hartz-Karp, J. A case study in deliberative democracy: Dialogue with the city. J. Public Delib. 2005, 1, 1–15.

71. Chava, J.; Newman, P.; Tiwari, R. Gentrification of station areas and its impact on transit ridership; Curtin University, Perth, WA, 2016.

72. Ministry of Housing and Urban Poverty Alleviation National Urban Housing and Habitat Policy; Report, Government of India, New Delhi, 2007.

73. Bangalore Housing Department Karnataka Housing and Habitat Policy; Report, Government of Karnataka, 2009.

74. RITES Comprehensive Traffic & Transportation plan for Bengaluru; Report for Karnataka Urban Infrastructure Development and Finance Corporation, Bengaluru, 2011.

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Manuscript 4: Transit Accessibility and Affordability Index: A tool to evaluate transit quality

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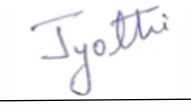

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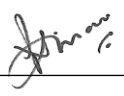

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Transit Accessibility and Affordability Index: A tool to evaluate transit quality

Abstract

The study introduces a composite transit performance index called Transit Accessibility and Affordability Index (TAAI). TAAI can be evaluated through a macro-level planning software. In contrast to the existing transit performance measures, which evaluate only accessibility, the tool evaluates both accessibility and affordability of transit. Transit quality can then be compared with other modes of travel and also other transit options. The tool has been applied to Bengaluru, India—as a case study, using the software TransCAD—to assess the performance of the city's existing bus transit, and the impact of the high-speed metro system (introduced in 2010) on transit performance. The case study shows the transit generalized cost (GC), composite measure of time and cost, decreased by 15% following the high-speed metro's introduction. However, transit GC is higher than that of the motorbike, and the car. This is attributable to: transit's higher access, egress and waiting times (out-of-vehicle time); lower average trip length; high transit fares; and to the minimal operating costs of private vehicles. In light of this cost difference, the study— recommends integrated strategies to make the transit system compete better with motorbikes, illustrating the value of the new tool (TAAI).

Keywords: Transit Performance Index, Accessibility, Affordability, Transit Generalised Cost

1 Introduction

Investment in a well-planned transit system is imperative for addressing various transport-related issues facing cities across the globe (Newman and Kenworthy, 2015). Transit can reduce congestion, emissions and accident rates; mitigate the city residents' travel cost burden and contribute to economic, environmental and social sustainability (Cervero and Kockelman, 1997; Cervero and Murakami, 2009; Litman, 2005; Lund et al., 2004; Mclntosh et al., 2013; Topalovic et al., 2012). To unlock this potential, investment in transit must be thoroughly planned. The envisaged transit system should help create dense centres of activity around stations, ease access among various origin and destination

(O&D) pairs through affordable fares for the majority, and be able to compete with alternative private modes of travel. These outcomes are all interrelated (Cervero, 1994; Newman and Kenworthy, 2015).

Quantifying a transit system's ease of access and affordability is a complex process, given the wide range of interrelated components involved. The four primary components used in this paper are spatial, temporal and network availability, and transit fares. Spatial availability assesses the physical proximity of a transit stop from the trip origin/destination; temporal availability estimates the opportunity for transit use based on attributes such as headway and operation hours; network availability measures transit route suitability to transport a patron from trip origin to destination; and transit fares calculates the money spent to travel along O&D pairs. Each component is weighted with users' preference and travel demand before being aggregated into a composite measure of accessibility and affordability.

The hitherto measures of quantifying transit system performance (described in detail in the literature review) have adopted different methodologies and assessed different aspects of transit accessibility, as a single measure or a combination of two to three integrated into one index. Most of these measures have neglected the affordability component. However, affordability is considered to be as equally important as accessibility in choosing the mode of travel, especially in a city in a developing economy (Zhao et al., 2002). To address this gap, the study intends to develop a tool with an inclusive mathematical structure, which weights the four primary accessibility measures as well as the affordability measure (discussed above) with the users' perceptions of temporal benefits, and then with the associated O&D demand.

The new tool (TAAI) is designed to enable planners and policymakers to develop transport options for the future, by identifying service gaps in the existing system through a comparison of transit options with competing alternatives. TAAI can also be used to assess the role of new transit plans in improved transit service quality. Overall, the tool can help provide answers to two questions:

Q1.How does the present transit system compare with alternatives (car/motorbike)?

Q2. How does proposed upgrading of the transit system improve the quality of transit service?

The first section of the study presents a literature review of existing transit performance measures, and highlights the methods adopted in their analysis. The second section describes the mathematical tool developed for the analysis, of accessibility and affordability of the current transit system in comparison with alternatives, and the impact of proposed transit plans on the quality of transit services. The third section describes the administration of the mathematical tool to the case study area of Bengaluru. This involves comparison of the bus system with its competitive modes (car and motorbike), and assessment of the potential impact of—operational and proposed sections of—the metro system. The subsequent section presents results from the case study, followed by a section on the conclusions—about the value of the tool—drawn.

2 Literature Review

Transit performance assessment studies exhibit an evolutionary trend. Some are limited to assessing spatial availability, by estimating the population within walkable distance of a transit stop/route. A few also consider temporal availability along with the spatial aspects, considering service within walkable distance may not be taken as 'available' if transit wait-time exceeds the potential rider's tolerable wait-time. Some studies amalgamate spatial, temporal and network availability into a composite measure. A few also weigh these supply side accessibility characteristics with demand distribution. However, the transit cost component does not feature in any of these studies. For a detailed understanding of the various transit performance measures adopted by these studies, the summary of each study is highlighted below chronologically, illustrating a growing complexity in the factors being considered.

Rood (1997) proposed the first comprehensive transit performance measure (of an area) called Local Index of Transit Availability (LITA). It integrates three aspects of transit service, namely spatial availability, temporal availability and, comfort and convenience. The three indicators representing the three aspects include service coverage (number of stops/land area), transit route headway (number of routes/hour) and capacity (seat-miles per capita). Although LITA addresses (to an extent) the local dimension of the demand,

while calculating capacity, it overlooks transit route availability at network level, and spatial demand distribution.

Hillman and Pool (1997) developed the Public Transportation Accessibility Level (PTAL) index. It measures the ease of traveling between O&D, using a composite measure of various temporal attributes, namely access time, waiting time, in-vehicle time, transfer time, and egress time. Based on this concept, Schoon et al. (1999) formulated an Accessibility Index (AI) for various modes. The AI of a mode is defined as the ratio of that mode's travel time to the average travel time across modes. The AI in terms of trip cost, is estimated in the same manner. Though PTAL and AI focus on service side characteristics such as the transit's spatial, temporal and network availability, they do not account for the travel demand side aspects.

Ryus et al., (2000) developed the Transit Level-Of-Service (TLOS) indicator. It considers: population within walkable distance of a transit stop; quality and safety of walkways; and transit frequencies. The measure expresses service availability in percent of person-minutes served. TLOS is unique, as it evaluates safety and comfort of walkways from trip origin to transit stops. However, as with LITA, TLOS is limited to the local dimension of demand (i.e. population size); it overlooks network level availability and spatial travel demand distribution (O&D distribution).

The Time-of-Day-Based Transit Accessibility Analysis tool developed by Polzin et al., (2002) is the first to consider temporal fluctuations in travel demand and service side characteristics. It includes spatial and temporal availability at trip ends, as well as temporal distribution of travel demand. This tool measures how well travel demand is served, using time-of-day travel demand distribution to determine the relative value of the transit service provided during each time period of the day. The travel demand distribution considered however, is limited to temporal variation along the transit route, not accounting for spatial demand distribution.

The Transit Capacity and Quality of Service Manual (TCQSM) (Kittelson & Associates, Inc., et al., 2003) allows a more systematic approach to evaluate transit service performance. For a fixed transit route, TCQSM proposes six levels of service measures viz. service availability (frequency, hours of service, service coverage) and service quality

(passenger load, reliability, transit-auto travel time difference). Aggregating all measures into a composite one is a complex process. While TCQSM covers all supply side and local-level demand side aspects, it does not consider affordability for evaluating the overall quality of transit.

A different approach was developed by Bhat et al., (2006) who created the Transit Accessibility Index (TAI) and the Transit Dependence Index (TDI) to identify patterns of inequity in service provision to population groups with different levels of need. TAI reflects the level of transit service supply by using a utility-based transit accessibility measure that incorporates spatial, temporal and network accessibility aspects. TDI on the other hand, indicates the potential level of transit need based on socio-demographic characteristics of potential transit users.

Fu and Xin (2007) then developed a new transit quality-of-service index, called Transit Service Indicator (TSI). Akin to the Schoon et al., (1999) approach, TSI compares transit and private vehicle travel time. By considering temporal fluctuation in demand and service side characteristics, it also adopts the Polzin et al., (2002) approach to an extent. Additionally, TSI weights user-perceived travel times by the associated O&D demand. The weighted travel times are then summed over all time periods and normalized by the total daily travel demand. This index has successfully incorporated demand and supply side characteristics into a composite measure, but does not include affordability.

Mamun and Lownes (2011) developed a composite accessibility measure by integrating LITA, TCQSM, and the Time-of-Day-Based Transit Accessibility Analysis tool. Their study proposes weighting factors for individual methods, to formulate a composite measure based on individual accessibility component measures. Curtis et al., (2012) developed a GIS based tool called Spatial Network Analysis of Multimodal Transport Systems (SNAMUTS) to assess the quality of the transit network between various nodes across a metropolitan area. SNAMUTS includes: transit travel time; frequency; number of transfers; population and job density; and travel times of the competitive modes. Mavoa et al., (2012) developed a Public Transit and Walking Accessibility Index (PTWAI) which assesses the accessibility of a zone by estimating the average transit travel time from that zone to all the others. These three methods consider demand at a local level (population

and job density) but ignore spatial demand distribution, while arriving at a composite measure.

All the methods highlighted in this section focus primarily on transit's accessibility component, overlooking the cost component. Mode choice models clearly indicate that cost is as important a factor as travel time especially in the developing world, in choosing one's mode of travel (Mohan and Tiwari, 2000). Likewise, in assessing the quality of transit, the cost component cannot be considered any less crucial. Hence, the study intends to assess transit performance by integrating the time and cost components. To arrive at a composite measure of time and cost, the study develops a mathematical formula combining the three accessibility elements, and the cost component. The detailed methodology adopted to develop the tool is highlighted in the next section.

3 Methodology

The study intends to assess the quality of transit at two levels, the first being the accessibility and affordability of the present transit system compared with the alternative competitive modes, and the second, the impact of the proposed upgraded transit system on the quality of transit services.

3.1 Quality of current transit system compared with alternatives

To assess the quality of the transit system in terms of accessibility and affordability, compared with the alternatives, the study proposes a three step method.

3.1.1 Step 1: Selecting zone size and time period of the day, for evaluating the TAAI

The assessment requires data on both service side characteristics (data on streets and transit routes), and demand side characteristics (temporal and spatial demand distribution). The first step of the study involves selecting the zone size, subject to data availability. TAAI assesses the transit performance at zone level. This indicates that the smaller the zone size, the better the results. Hence, the study recommends choosing block level data over census-tract level data, if available. Next, we decide whether or not to consider time of day fluctuations in service side and demand side characteristics. If all required data sets corresponding to each time period of the day are available, we can assess TAAI for each time period and weight each with the respective travel demand. The weighted TAAI can

then be aggregated over all time periods, and normalized by total daily travel demand (equation 7).

3.1.2 Step 2: Assessing transit availability through spatial and temporal accessibility analysis

After finalising zone size and time of day for which to carry out the analysis, we classify zones into two types based on transit availability for each time period of the day, by assessing the spatial and temporal availability of each zone. The measure of availability reflects if transit can at all be considered a potential mode choice for each zone during that period of the day. Availability assessment involves two steps:

1. The first step involves identification of routes operating at *acceptable frequency for each time period of the day.* Acceptable frequency is fixed at twice the tolerable wait time of a potential transit rider. It varies for different persons and places. Hence, the planner must ascertain it based on local conditions.
2. Once the routes are identified, define the transit service area by creating a buffer of *acceptable walkable distance/time around each route stop* (Horner and Murray, 2004). Select the set of zone centroids falling within the transit service areas, and create a selection set of these zones for assessing the TAAI. A common practice in transit planning is assuming that people are served by transit if they are within 400m to 800m of either a transit route or stop (Alshalalfah and Shalaby, 2005; Advani and Tiwari, 2006; Guerra et al., 2011; Ramirez and Seneviratne, 1996; Yigitcanlar et al., 2007; Zhao et al., 2003). However, it is up to the transport planner to determine the exact allowable walkable distance based on the cities' local conditions and users' perception.

3.1.3 Step 3: Assessing transit accessibility and affordability through TAAI

The study intends to assess transit accessibility and affordability by comparing them with that of the competitive private mode of travel, for the identified set of zones with transit availability. Hence, TAAI is expressed in percentage of higher/lesser generalized cost that the transit incurs when compared with the competitive private mode (equation 1). The mathematical derivations are set out below.

$$TAAI_{(i,j)} = \left[\frac{GC_{(i,j,PT)} - GC_{(i,j,PV)}}{GC_{(i,j,PV)}}\right] \times 100 \qquad (1)$$

TAAI for the trips produced in zone *i* (for the trips produced in zone *i* and attracted to 'n' number of zones)

$$TAAI_{(i\varepsilon\, O)} = \sum_{j=1}^{n}\left[\frac{TAAI_{(i,j)} \times OD_{(i,j)}}{\sum_{j=1}^{n} OD_{(i,j)}}\right] \qquad (2)$$

TAAI for the trips attracted to zone *i* (for the trips produced in 'n' number of zones and attracted to zone *i*)

$$TAAI_{(i\varepsilon\, D)} = \sum_{i=1}^{n}\left[\frac{TAAI_{(i,j)} \times OD_{(i,j)}}{\sum_{i=1}^{n} OD_{(i,j)}}\right] \qquad (3)$$

Depending on the number of trips produced in and attracted to zone *i*, the zone could yield different TAAI results for the trips produced and attracted. Hence, in contrast to existing public transit quality models, the study contemplates different TAAI values for the trips produced in, and for the trips attracted to zone *i* (equations 2 and 3).

Where

$TAAI_{(i,j)}$ = Transit accessibility and affordability index from zone *i* to zone *j*

$TAAI_{(i\varepsilon\, O)}$ = Transit accessibility and affordability index for the trips produced in zone *i*

$TAAI_{(i\varepsilon\, D)}$ = Transit accessibility and affordability index for the trips attracted to zone *i*

$GC_{(i,j,PT)}$ = Generalized cost of public transit from zone *i* to zone *j*

$GC_{(i,j,PV)}$ = Generalized cost of private vehicle travel from zone *i* to zone *j*

$OD_{(i,j)}$ = Travel demand from zone *i* to zone *j*

n = Number of census tracts/blocks for which transit is available

To assess the overall TAAI for zone *i*, we weight TAAI for trips produced in zone *i* with the respective trip production, and weight TAAI for trips attracted in zone *i* with the respective trip attraction, and normalize the weighted TAAIs with the total trips produced in, and attracted to zone *i*, and aggregate both the values (equations 4, 5 and 6).

$$TAAI_{(i)} = WTAAI_{(i\varepsilon\, O)} + WTAAI_{(i\varepsilon\, D)} \qquad (4)$$

$$WTAAI_{(i\varepsilon\, O)} = \frac{TAAI_{(i\varepsilon\, O)} \times P_{(i)}}{P_{(i)} + A_{(i)}} \qquad (5)$$

$$WTAAI_{(i\varepsilon\, D)} = \frac{TAAI_{(i\varepsilon\, D)} \times A_{(i)}}{P_{(i)} + A_{(i)}} \qquad (6)$$

Where

$TAAI_{(i)}$ = Transit accessibility and affordability index for zone *i*

$WTAAI_{(i\varepsilon\, O)}$ = Weighted TAAI of zone *i* for the trips produced

$WTAAI_{(i\varepsilon\, D)}$ = Weighted TAAI of zone *i* for the trips attracted

$P_{(i)}$ = Number of trips produced in zone *i*

$A_{(i)}$ = Number of trips attracted to zone *i*

If the TAAI of a zone is estimated by considering temporal fluctuations, and estimated for each time period of the day, then we calculate the average TAAI of zone *i* (equation 7).

$$TAAI_{(i)} = \sum_{z=1}^{t} \left[\frac{TAAI_{(i,z)} \times (P_{(i,z)} + A_{(i,z)})}{\sum_{z=1}^{t} (P_{(i,z)} + A_{(i,z)})} \right] \qquad (7)$$

Where

$TAAI_{(i,z)}$ = Transit accessibility and affordability index for zone *i* during the time period *z*

$P_{(i,z)}$ = Number of trips produced in zone *i* during the time period *z*

$A_{(i,z)}$ = Number of trips attracted to zone *i* during the time period *z*

t = Number of time periods considered during a day

3.1.3.1 Assessing generalized costs of transit and private vehicle travel

The TAAI is expressed in percentage of higher/lesser GC that transit incurs when compared with that of private vehicle travel. Hence, it is necessary to accurately assess GC of each mode for each O&D pair. GC is the aggregation of accessibility and affordability components (equations 8 and 9). To assess the accessibility component, the study intends to use travel times, as by Fu and Xin (2007), Hillman and Pool (1997), Schoon et al., (1999). To assess affordability, the study considers transit fares.

$$GC_{(i,j,PT)} = TT_{(i,j,PT)} + TC_{(i,j,PT)} \quad (8)$$

$$GC_{(i,j,PV)} = TT_{(i,j,PV)} + TC_{(i,j,PV)} \quad (9)$$

Transit travel time: It includes: walking time (to access, egress and at transfers); waiting time; and in-vehicle time. The study acknowledges, as Lesley (2001) suggested, that total perceived transit travel time is different from actual travel time. Perceived travel time could be higher/lower than the actual, based on various elements in the system. For example, in a neighbourhood suitable for walking, perceived travel time for walking is likely to be lower than actual travel time, while the opposite is true for congested and littered streets. A number of studies have been conducted to quantify the perception of different components of PT travel time (Iseki et al., 2006; Van Exel and Rietveld, 2010). According to these studies, the perceived out of vehicle travel time, which includes walking, transfer and waiting time, is 1.5 to 2.2 times higher than the actual time. The studies also mention that the perception often varies based on trip purpose, total travel time, and availability of other modes. Hence, to account for transit riders' perception of travel time, weighting factors are to be determined by transport planners, based on local conditions. Transit in-vehicle time is calculated by mode and link, considering each mode and link has different speeds.

$$TT_{(i,j,PT)} = W^{Wk}WT_{(i,j,PT)} + W^{tw}TW_{(i,j,PT)} + W^{ivt}IVT_{(i,j,PT)} \quad (10)$$

$$WT_{(i,j,PT)} = \frac{(d^{AS}+d^{ES}+d^{TS})}{S_{wk}} \quad (11)$$

$$IVT_{(i,j,PT)} = \sum_{m=1}^{k}\left[\frac{\sum_b L_b(i,j,PT)}{S_m}\right] \quad (12)$$

$$TW_{(i,j,PT)} = \sum_{x=1}^{tr}\frac{H_x(i,j,PT)}{2} \quad (13)$$

Where

$TT_{(i,j,PT)}$= Total travel time to reach from zone *i* to *j* by public transit

$WT_{(i,j,PT)}$ = Walking time from zone *i* to *j*

$TW_{(i,j,PT)}$ = Waiting time for transit from zone *i* to *j*

$IVT_{(i,j,PT)}$ = In-vehicle transit travel time to travel from zone *i* to *j*

W^{wk}, W^{tw}, W^{ivt} = Weighting coefficients for walking, waiting and in-vehicle time to account for user perceived travel time

d^{AS}, d^{ES}, d^{TS}= Access distance, egress distance and walking distance at transfers

$L_b(i,j,PT)$ = Length of a link 'b' travelled by mode 'm' to travel from zone *i* to *j*

S_m = Travel speed of transit mode 'm'

S_{wk} = Walking speed

k = Number of transit modes used to travel between zone *i* to *j*

$H_x(i,j,PT)$ = Head way of the route system '*x*'

tr = Number of the route system required to travel from zone *i* to *j* by transit

Private vehicle travel time: It includes in-vehicle time, and walking time, if any (from trip origin to parking location, or parking location to trip destination). The in-vehicle time is calculated for each link, considering different links have different travel speeds.

Where

$$TT_{(i,j,PV)} = W^{ivt} IVT_{(i,j,PV)} + W^{Wk} WT_{(i,j,PV)} \qquad (14)$$

$$IVT_{(i,j,Pv)} = \sum_a \frac{L_a(i,j,PV)}{S_{PV}} \qquad (15)$$

Where

$TT_{(i,j,PV)}$ = Total travel time to reach from origin *i* to destination *j* by private vehicle

$IVT_{(i,j,PV)}$ = In-vehicle travel time of private vehicle user from zone *i* to zone *j*

$WT_{(i,j,PV)}$ = If applicable, walking time from trip origin to parking lot, or parking lot to trip destination

$L_a(i,j,PV)$ = Length of the link 'a' travelled by private vehicle, to travel from zone *i* to zone *j*

S_{PV} = Speed of private vehicle

Travel costs of transit and private vehicle: Transit fares are estimated from one zone to another and converted into time units using the potential transit rider's value of time

(VOT). Private vehicle travel costs are estimated by considering various parameters (separately for each private vehicle type), namely toll price, parking fee, and vehicle operating costs from one zone to another. They are converted to time units using the VOT of users of the particular private vehicle type (generally, each cost parameter and VOT varies for motorbike and car user).

$$TC_{(i,j,PT)} = \left[\frac{F_{(i,j,PT)}}{VOT_{(PT)}}\right] \times 60 \qquad (16)$$

$$TC_{(i,j,PV)} = \left[\frac{\sum_a L_{a(i,j,PV)} \times VOC + P_{(j,PV)} + T_{(i,j,PV)}}{VOT_{(PV)} \times OC_{(PV)}}\right] \times 60 \qquad (17)$$

Where

$F_{(i,j,PT)}$ = Transit fare from zone *i* to *j*

$VOT_{(PT)}$= Value of time of a public transit user ($/hr)

VOC = Vehicle operating cost ($/km)

$P_{(j,PV)}$ = Private vehicle parking cost at destination *j* ($)

$T_{(i,j,PV)}$ = Toll fee for private vehicle from origin *i* to destination *j* ($)

$OC_{(PV)}$ = Occupancy of a private vehicle

3.2 Impact of proposed transit system on transit quality

Assessing the impact of the new transit system helps planners and policymakers to come up with the best transit expansion plan. In the current study, the impact is assessed in two ways, as highlighted below.

3.2.1 Quality of the current and proposed transit system compared with alternatives

To assess the impact of the proposed transit, we estimate the TAAI of the existing and proposed transit systems taken together, using the steps highlighted above.

3.2.2 Assessing percentage of savings in transit generalized cost

Every city is unique and may require different transit plans to address its transport needs. The savings in transit GC can serve as a basis for policymakers to decide on future transit plans for their cities. The study proposes the following equation to further understand the

percentage of savings in each zone's transit GC, achieved due to the proposed upgraded transit system.

$$GCS_{(i)} = \left(\frac{GC_{(i,\ EPT)} - GC_{(i,\ FPT)}}{GC_{(i,\ EPT)}}\right) \times 100 \qquad (18)$$

$$GC_{(i,\ EPT)} = \sum_{i=1}^{n} \frac{GC_{(i,j,PT)} \times OD_{(i,j,PT)}}{\sum_{i=1}^{n} OD_{(i,j,PT)}} \qquad (19)$$

$$GC_{(i,\ FPT)} = \sum_{i=1}^{n} \frac{GC_{(i,j,PT)} \times OD^{HY}_{(i.j,PT)}}{\sum_{i=1}^{n} OD^{HY}_{(i.j,PT)}} \qquad (20)$$

Where

$GCS_{(i)}$ = Percentage of generalized cost savings of zone *i* due to proposed transit plans

$GC_{(i,EPT)}$ = Total generalized cost of zone *i* with the existing transit system

$GC_{(i,FPT)}$ = Total generalized cost of zone *i* with the existing and the future transit system

$OD_{(i,j,PT)}$ = Public transit travel demand from zone *i* to *j* during the base year

$OD^{HY}_{(i.j,PT)}$= Public transit travel demand from zone *i* to *j* during the horizon year

The TAAI tool will now be applied to Bengaluru to demonstrate its value.

4 Applying the TAAI tool in the case study of Bengaluru

The study administered the proposed TAAI tool in the Indian city Bengaluru. Using the TAAI, the quality of the existing bus transit system, and the impact of a newly operational and expanding metro, towards improving the city's transit service quality are assessed. The step-by-step methods adopted, and various assumptions considered during the transit quality assessment, are highlighted below.

Bengaluru, with a population of around 8.5 million, is India's third most populous city. Until 2010, bus was the only constituent of the transit system here, with around 1800 routes connecting the city centres and suburbs, run by the Bangalore Metropolitan Transportation Corporation Limited, or BMTC (Bangalore Metropolitan Transport Corporation Limited, 2015) . The metro started operations in 2010, and currently runs on a 32 km stretch; a 83 km stretch is under construction and eventually will cover 114.5 km

(Bangalore Metropolitan Rail Corporation Limited, 2015). The TAAI tool is applied in the city of Bengaluru at two levels:

1. To assess the quality of the present bus transit system in comparison with other competitive modes
2. To assess the impact of the metro (114.5 km), towards improving the transit performance

4.1 Quality of bus transit system compared with alternatives

4.1.1 Step 1: Selecting zone size and time period of the day, for evaluating the TAAI

According to Bruhat Bangalore Mahanagara Palike (BBMP), the city had 191 zones (Bruhat Bangalore Mahanagara Palike, 2015) in 2011; the same zones are adopted by the Comprehensive Traffic and Transportation Plan (CTTP) of Bengaluru (RITES, 2011). The CTTP is the sole source for estimating demand side characteristics. Hence, the study considers the same zones as the CTTP, to estimate the TAAI. The 191 zones are digitized in a GIS based software called TransCAD along with their characteristics such as population, employment, and education enrolment, based on the CTTP report. The report does not provide the temporal fluctuations in travel demand.

The service side characteristics of transit modes are gathered from various open sources. The bus service side characteristics (data on routes, headway, and bus stop location) are sourced from the BMTC, and the metro service side characteristics from the Bangalore Metropolitan Rail Corporation Limited (BMRCL). The data reflects that average frequency is almost the same during peak and off-peak time. This is attributable to the fact that schedules are implemented without any measures to respond to temporal fluctuations in demand.

The street network, along with characteristics including name and street type, is sourced from Geofabrik (2015), and mode specific average speeds for each street type from CTTP. The CTTP report does not provide mode specific speeds for peak and off-peak periods, for considering temporal fluctuations. As such, due to unavailability of data, the study did not account for temporal fluctuations in demand side and service side characteristics; it estimates only average TAAI for each zone.

4.1.2 Step 2: Assessing transit availability through spatial and temporal accessibility analysis

Before assessing the TAAI, the study segregates the zones based on transit availability. To assess the availability, as Curtis et al., (2012) suggested, the study assumes that the average acceptable waiting time of a potential transit rider is 10 min. Hence, routes with an average frequency of less than 20 mins are identified. Of approximately 1800 transit routes in the city, only 91 meet this criterion. These 91 routes are digitized (using TransCAD) along with their average frequency. TransCAD allows for the routes to be digitized only on the street network; transit attributes such as speed and travel time are also registered as part of the street network. Hence, before digitizing the routes, the street network is digitised along with characteristics such as each link length, street type, mode specific average speeds, and travel times. The average private vehicle speed on each street type is determined based on the CTTP report. Bus travel times are assumed as 20% higher than private vehicle travel times, to account for the dwell time at each bus stop, as suggested in the CTTP (RITES, 2011)**.** Metro average speed is considered as 34 kph (Bangalore Metropolitan Rail Corporation Limited, 2016) and walk speed is assumed as 4kph. Based on average speed and link length, the travel time on each link, for each mode, is estimated.

After digitizing the streets and route network, a buffer is created, for which route stops are to be considered (instead of routes) as they are the exact location where people access transit (Hillman and Pool, 1997). To identify the transit service area, a buffer approximately 650 m in length is created around each route stop, as 650 m is proven as the acceptable 10 min walkable distance in Indian conditions (Johar et al., 2015). Using the ‘selection’ option in TransCAD, zone centroids falling within the identified service area are selected for further analysis. The analysis reveals of the 191 zones, 30 zone centroids fall outside the service area, thus representing zones where transit is not a realistic option. As highlighted in Figure 1, transit availability is inversely proportional to distance from the central business district (CBD). Additionally, the ‘overlay’ analysis in TransCAD indicates that out of the total area, the transit service area covers around 30% of the metropolitan area, serving around 79% of the population.

4.1.3 Step 3: Assessing transit accessibility and affordability through TAAI

As TAAI compares transit quality with that of the competitive mode, its evaluation requires that we identify the competitive alternative mode of travel. Though the study compares public transit quality with that of both car and motorbike; in Indian conditions, motorbike is a more competitive travel mode versus transit, than car. With improving social status, people in India often move from public transit to motorbike (Tiwari, 2011). The next section illustrates how to assess the GC of three modes: car, motorbike, and existing transit.

4.1.3.1 Generalized cost estimation for transit, car and motorbike

To estimate transit, car and motorbike GCs, the study used certain assumptions, based on the CTTP, and BMTC studies (Parwez, 2013; RITES, 2011). The CTTP study included a detailed HH survey of 26,000 households, based on which it derived the perceived travel times of different time components of transit, in the case city of Bengaluru. The current study assumes the same values (listed below) as the CTTP study. The BMTC study included a detailed comparison of the travel cost of different modes in Bengaluru. The present study ascertained the vehicle operating costs for various modes from the BMTC study. Based on these assumptions (listed below), the three modes' travel times and cost are estimated, and aggregated specific to mode, to yield mode specific GC for each O&D pair.

- Weighting coefficient for walking distance = 1.2
- Weighting coefficient for waiting time = 2
- Weighting coefficient for in-vehicle travel time = 1
- Value of time of a potential transit rider = INR 26
- Value of time of a motorbike user = INR 54
- Value of time of a car user = INR 89
- Vehicle operating cost per km for motorbike = INR 2.3
- Vehicle operating cost per km for car = INR 6.76
- Vehicle occupancy for a motorbike = 1.53
- Vehicle occupancy for a car = 2.59

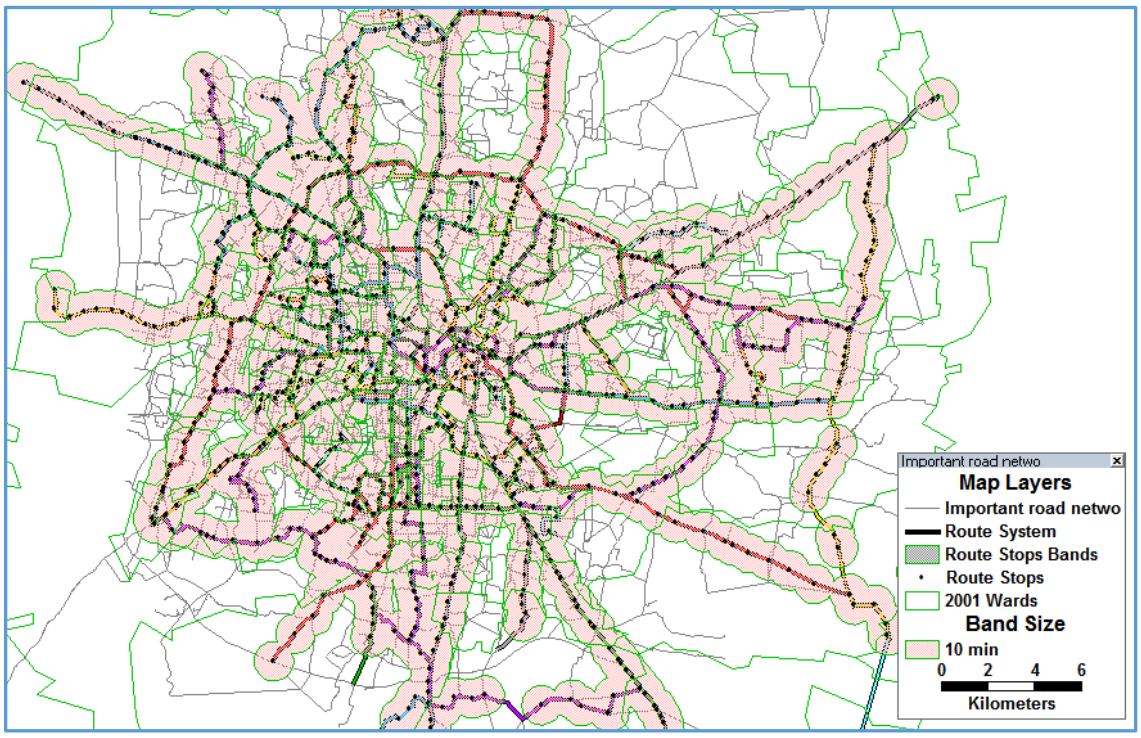

Figure 1: Checking spatial and temporal availability

Transit travel time: TransCAD offers various options to estimate the transit travel time for an O&D pair. The study adopts the Optimal Strategy Method (OSM). OSM assumes that at a particular bus stop, the passengers boarding for the same destination may not all travel by the same route; it is realistic to expect that they may board different buses taking different routes. Based on this assumption, the OSM algorithm in TransCAD calculates the transit travel time of the best path, among the selected set of zones, using weighted coefficients (above), as well as in-vehicle transit travel times, frequencies, and walk travel times.

Motorbike and car travel time: Estimating travel time for private vehicles is easier than for transit. Motorbike and car travel time—among all the selected zones—is estimated based on link-specific motorized vehicle travel time. The access and egress walk times (to and from parking lots) are ignored.

Transit costs: In Bengaluru, transit fares depend on the distance travelled; the fare per km decreases as distance travelled increases. To account for this variation, public transit route lengths—among all the selected zones—are estimated. Transit fares are estimated using

the BMTC price chart and transit distance between O&D, and converted into time units using the transit rider's VOT.

Motorbike and car travel costs: Currently in Bengaluru, most locations are free of parking charges, and there are no toll gates in the city. Hence, travel cost estimation involves only the vehicle operating costs (includes vehicle wear and tear) incurred in travel between each O&D pair. To estimate motorbike and car travel costs, and convert them into travel time (minutes), the estimated distance between each O&D pair, the respective operating costs, and the respective VOTs are applied to equation 17.

The travel cost and time component of each mode is aggregated to estimate GC for each mode. After the service side characteristics, the demand side characteristics are assessed, to evaluate the TAAI.

4.1.3.2 Demand estimation

Most developed countries have access to the O&D transport demand data but in Bengaluru, India this data is not available. The study relies on zone based population, employment, and student enrolment data (RITES, 2011). Trip distribution is derived using the first two steps of four-step modelling.

Trip Generation: This is the first step in four-step modelling. It predicts the number of trips produced in and attracted to (P&A) each zone. The study estimates trip P&A of each zone based on three variables: purpose of trip, vehicle availability and HH size. Purpose of trip is classified into four categories viz. Home Based Work (HBW), Home Based Education (HBE), Home Based Business (HBB), and Home Based Other (HBO). Vehicle availability is grouped into three categories viz. No Vehicle available (NV); Car available (Car); and Motorbike available (MB). HH size is grouped into six categories. These three variables yield 72 sub models (4x3x6). The study estimates the trips produced in each zone using the CTTP trip rates per capita for each sub model. Once the trips produced in a TAZ were estimated for 72 sub models, the 6 HH size groups of the respective trip purposes and the vehicle availability groups, were aggregated and converted to 12 (4x3) trip production sub models for each TAZ (four trip purposes and three vehicle availability groups). Based on the employment, education, and business opportunities of each zone in

2015, the HBW, HBE and HBB trips produced were proportionally distributed among 191 CTs. The HBO trips were proportionally distributed based on the population of each CT.

Trip Distribution: Trip distribution models help predict the spatial pattern of trips between origins and destinations. There are various models and various impedance factors (travel time, cost or GC) for predicting the O&D matrix. The study uses doubly constrained gravity model, using GC as an impedance factor to distribute the trips between various O&D pairs. The coefficient for gravity model is adopted from CTTP. Based on the CTTP calibration coefficients of 12 sub models, 12 P&A tables are distributed among 191 zones.

4.1.3.3 Estimating TAAI

Using the mode specific GC and travel demand between each O&D pair, each zone's TAAI—with respect to car and motorbike—is estimated using equations 1 to 6. TAAI reflects how high (in percentage) the transit GC is, when compared with that of motorbike and car (Figure 2 and Figure 3). The analysis shows that transit users incur higher GC than motorbike and car users. Transit GC exceeds motorbike GC significantly more than it exceeds car GC (Table 1). As shown in Table 1, for almost all the zones except 2, the transit GC is 100 % higher than that of motorbike and for around 50% of the zones, transit GC is 100% higher than that of car. This indicates that current transit users are captive users, without accessibility to private modes. Thus, in a do-nothing scenario, as their social status improves, people gradually shift to private modes, especially motorbike, due to its lower GC than that of the current transit system.

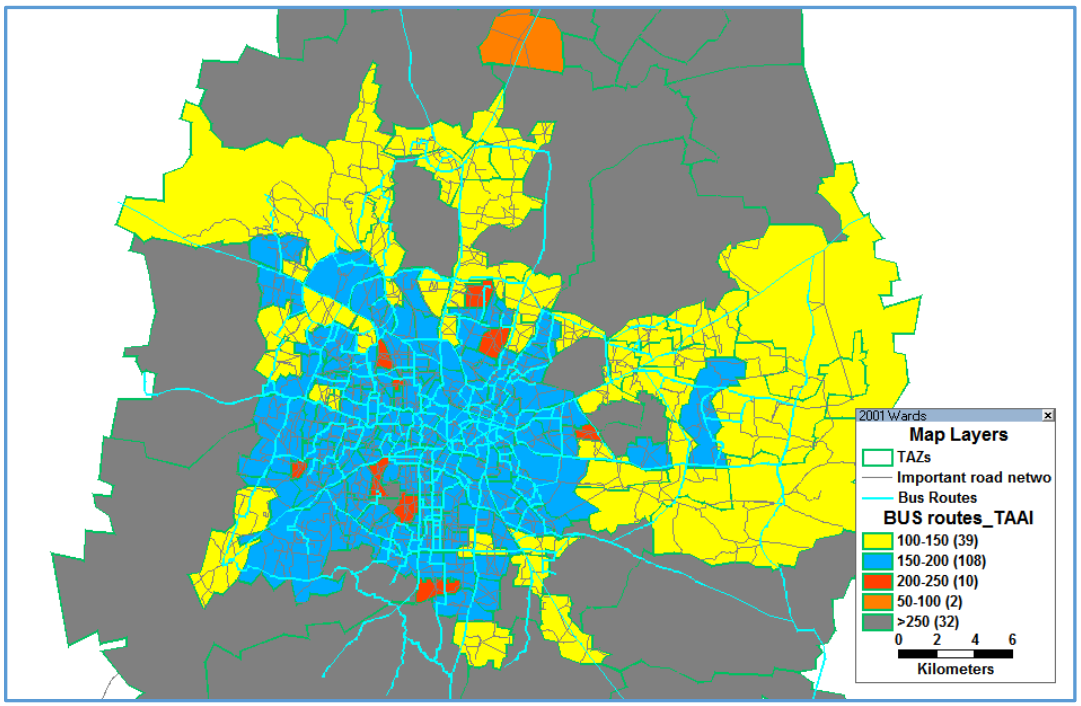

Figure 2: Transit Accessibility and Affordability Index for bus routes in the city of Bengaluru, compared with motorbike

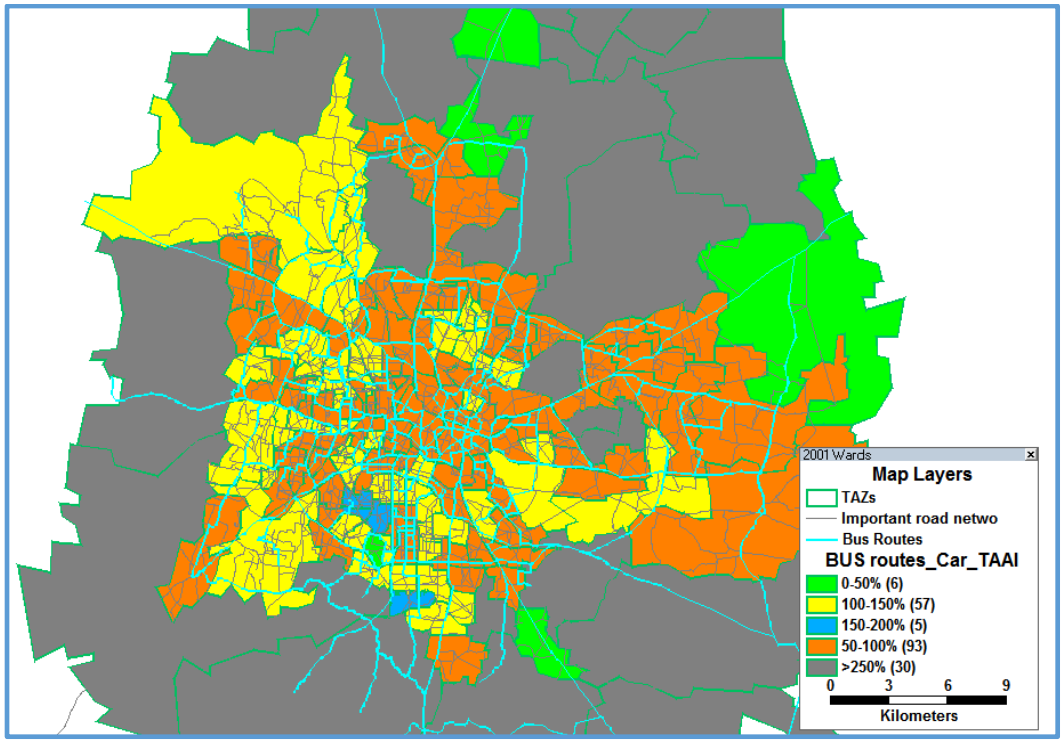

Figure 3: Transit Accessibility and Affordability Index for bus routes in the city of Bengaluru, compared with car

4.2 Impact of the proposed transit system on transit quality

To assess the impact of the proposed transit on transit quality, the quality of bus and (operating and proposed) metro together, is compared with that of alternatives, and the percentage of savings in transit GC, following the metro's introduction, is estimated.

4.2.1 Quality of current and proposed transit system compared with alternatives

To estimate the quality of the bus and metro transit system, the proposed and operational metro routes are included with the 91 bus routes, and the new transit GC is estimated using steps explained above. To calculate the combined transit travel times of using both bus and metro, mode table is used to determine the transit travel speeds and, maximum access and egress time, for each mode. The combined bus and metro fares are estimated by calculating bus and metro route length separately, and applying the respective fares between each O&D pair. Demand distribution for the horizon year (2025) is estimated using the CTTP data. Once the service side and demand side characteristics are assessed for the horizon year, each zone's combined bus and metro TAAI with respect to motorbike and car, is estimated (Figure 4 and Figure 5). For most of the zones, the combined TAAI of bus and metro shows substantial improvement when compared with that of the bus routes, as highlighted in Figure 4 and Figure 5 and Table 1. With its high speed, the metro has succeeded in improving the TAAI with respect to both motorbike and car. The lesser the distance between a station and the zone centroid, the better is the TAAI. For zones close to the metro station, transit is very competitive with the car. For around 40% of the zones, transit GC is 0-50% higher than that of the car. For more than 50% of the zones, transit GC is 0-100% higher than that of motorbike.

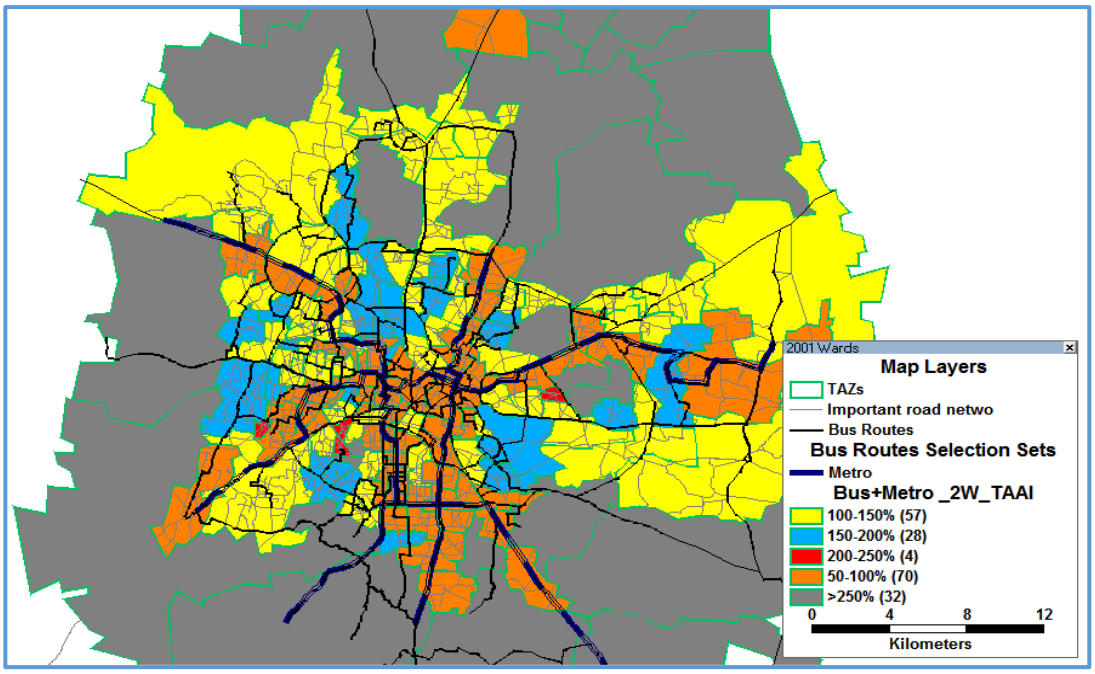

Figure 4: Impact of the existing and proposed metro on TAAI in the city of Bengaluru (Compared with motorbike)

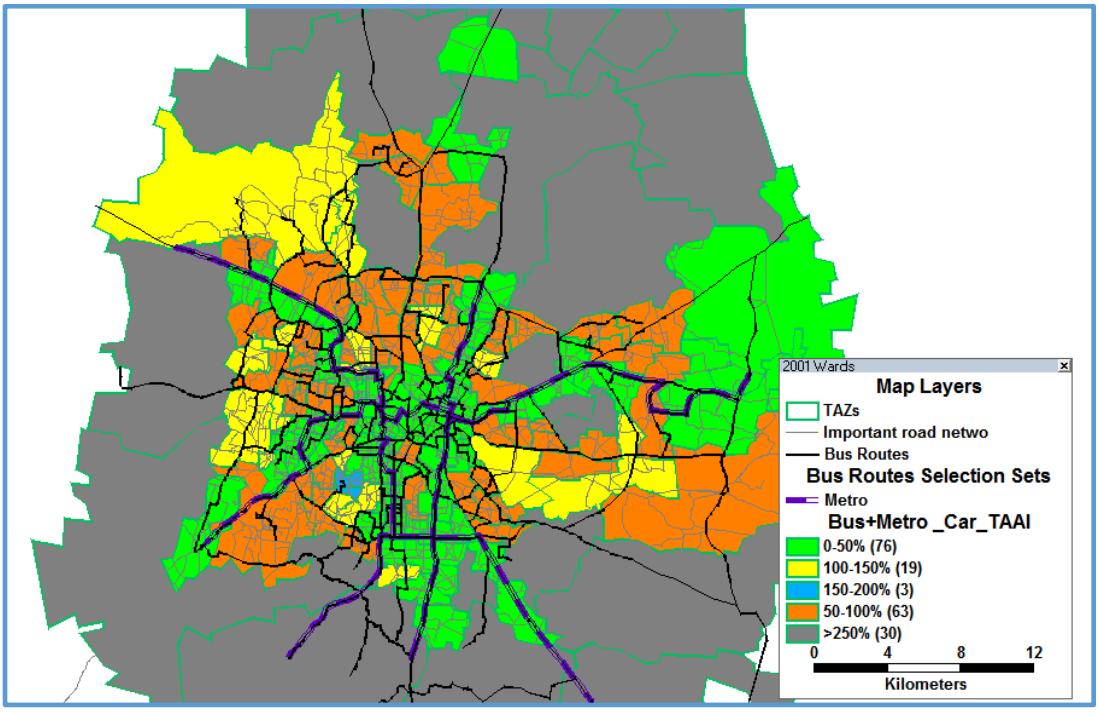

Figure 5: Impact of the existing and proposed metro on TAAI in the city of Bengaluru (Compared with car)

4.2.2 Assessing percentage of savings in generalized cost

The GC savings are expressed as the percentage of savings in GC for the horizon year, compared with the base year as shown in equations 18 to 20. The percent GC savings of each zone are showcased in Figure 6. The figure indicates that the closer the zones to the metro station, the more the GC savings. For greater GC savings, metro's benefits must be optimised, by extending the metro service area's accessibility to users who are not within walkable distance (400 m to 800 m) from it. This is achievable by improving last mile connectivity.

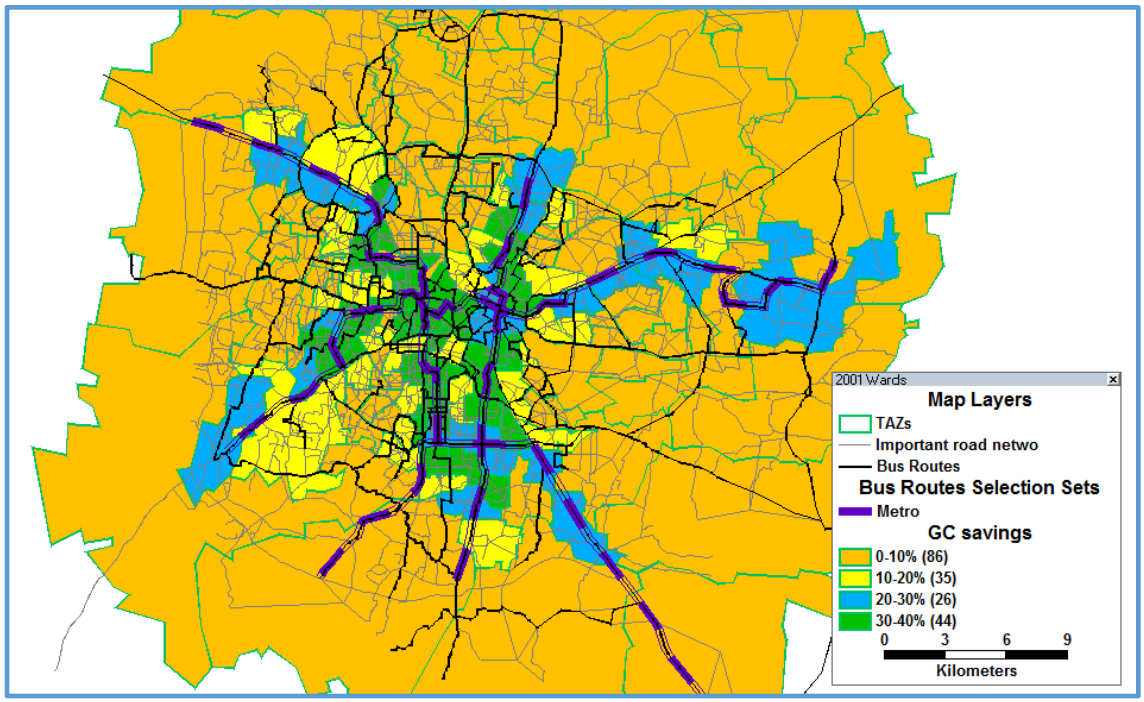

Figure 6: The percentage of generalized cost savings of each zone following the metro's introduction

5 Overview of results from the case study analysis

Table 1: Number of zones and their TAAI range (Percentage by which transit GC is higher compared with competitive mode)

	TAAI with respect to motorbike		TAAI with respect to car	
	Bus transit	Bus and Metro transit	Bus transit	Bus and Metro transit
0-50%	0	0	6	76
50-100%	2	70	93	63
100-150%	39	57	57	19
150-200%	108	28	5	3
200-250%	10	4	0	0
>250%	32	32	30	30
Sum	191	191	191	191

The case study analysis indicates that bus transit GC is higher than that of motorbike and car travel. Of the 191 zones identified in Bengaluru, 30 are without bus transit access; 161 are served by bus routes. The bus routes' TAAI analysis indicates that people in these zones incur significantly higher GC in bus transit than in motorbike travel. Hence, the case study analysis signals the reason why people give up transit for motorbike.

The combined bus and metro TAAI reflects that metro has not improved spatial availability, as most of the metro routes are along existing bus routes. With reduced in-vehicle transit travel time owing to its higher speed, metro competes with the motorbike and car to an extent, especially in zones close to the metro station. Additionally, the introduction of the metro has reduced the average GC of transit by almost 15%. However, the metro could compete better with the motorbike and the car if not for its higher perceived access, egress and waiting times (out-of-vehicle times); smaller trip length; higher transit fares; and motorbike's low operating cost. Hence, measures to reduce the out-of-vehicle time are required in order, to reduce the overall GC. It can be achieved by improving walkways and cycle paths, and introducing placemaking at transit stops, as in Hong Kong, where rail stations are designed along the lines of a large public space. As Bertolini and Spit (1998) suggest, stations must be designed as 'places to be' rather than 'places to go through'. These measures help reduce the transit users' perception of travel time, while they access, egress and wait at the transit stop. The reduced perceived out-of-

vehicle travel times along with the reduced in-vehicle travel times can contribute to reducing the overall GC. These can optimise transit ridership, and minimise mode shift from sustainable modes (transit and non-motorized transport) to unsustainable private modes. Extending the transit routes to zones which are currently not served by transit, can also contribute significantly to improving transit quality.

Additionally, discouraging private vehicle usage through congestion pricing, paid parking, giving priority to buses at intersections, and discouraging car ownership by collecting higher road tax, are all likely to help make transit a better mode of travel (Ahluwalia et al., 2014).

6 Conclusions on TAAI tool

This study introduced the Transit Service Accessibility and Affordabilty Index (TAAI), a composite index that can be used for evaluating both accessibility and affordability aspects of transit. The tool differs from existing transit performance measures outlined in the literature review in that it incorporates the time and cost components into one composite measure, and also integrates demand characteristics and user preferences into one equation.

The tool has been used successfully to evaluate transit's spatial, temporal and network availability, and transit fares. Its application to Bengaluru has been demonstarted. It allowed a unique opportunity to evaluate transit quality by aggregating cost and travel time components into GC, comparing transit GC with that of its competitive mode of travel and, assessing the impact of new transit proposals on transit quality. In developing and developed countries, new transit routes are sometimes introduced due to political pressure without any scientific evaluation. For example in Bengaluru, BMTC determines new routes based on political pressure, or chooses the existing bus routes facing overcrowding. There is no simple scientific mechanism to assess the impact of such new routes in improving transit quality. In such a situation, the TAAI tool can help scientifically identify the new routes, and assess their impact on transit quality. It can also facilitate a way to determine transit fares based on the travel cost of competitive modes.

Though the tool involves a lot of data, cities can use it while preparing their comprehensive mobility plans (CMP), and transportation and traffic studies. The data

collected during these studies can be used to assess the transit quality of different services, using the TAAI. The TAAI tool enables that conducting a transit quality performance assessment be considered a prerequisite whilst developing city level transportation studies, thus enabling policy makers and planners to identify how to make transit a more competitive mode rather than simply developing a road plan.

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References

Advani, M., Tiwari, G., 2006. Bicycle - As a feeder mode for bus services, in: VELO MONDIAL Conference. 5-10 March, Cape Town, South Africa.

Ahluwalia, I.J., Kanbur, R., Mohanty, P.K., 2014. Urbanisation in India: Challenges, Opportunities and the Way Forward. SAGE Publication, India.

Alshalalfah, B., Shalaby, A., 2005. Relationship between walk access distance to transit Socioeconomic, demographic and transit service characteristics., in: 84th Annual Meeting of Transportation Research Record. January 9–13, Washingon D.C.

Bangalore Metropolitan Rail Corporation Limited [WWW Document], 2016. URL www.bmrc.co.in

Bangalore Metropolitan Transport Corporation Limited [WWW Document], 2015. URL mybmtc.com

Bertolini, L., Spit, T., 1998. Cities on Rail. Spon Press, London.

Bhat, C., Bricka, S., Mondia, J. la, Kapur, A., Guo, J., Sen, S., 2006. Metropolitan Area Transit Accessibility Analysis tool. Report, National Center for Transportation Research, University of South Florida. Report no: 0-5178-P3.

Bruhat Bangalore Mahanagara Palike [WWW Document], 2015. URL bbmp.gov.in

Cervero, R., 1994. Transit-based housing in California: evidence on ridership impacts. Transp. Policy 1, 174–183. doi:10.1016/0967-070X(94)90013-2

Cervero, R., Kockelman, K., 1997. Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon 2, 199–219.

Cervero, R., Murakami, J., 2009. Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Stud. 46, 2019–2043. doi:10.1177/0042098009339431

Curtis, C., Scheurer, J., Mellor, R., 2012. Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS). Report for European Cooperation in Science and Technology.

Fu, L., Xin, Y., 2007. A New Performance Index for Evaluating Transit Quality of Service. J. Public Transp. 10, 47–69.

Geofabrik [WWW Document], 2015. URL download.geofabrik.de (accessed 11.10.15).

Guerra, E., Cervero, R., Tischler, D., 2011. The Half-Mile Circle: Does It Best Represent Transit Station Catchments? Report, Institute of Transportation Studies, University of California, Berkeley.

Hillman, R., Pool, G., 1997. GIS-based Innovations for modeling public transport accessibility. Traffic Eng. Control 38, 554–559.

Horner, M.W., Murray, A.T., 2004. Spatial representation and scale impacts in transit service assessment. Environ. Plan. B Plan. Des. 31, 785–797. doi:10.1068/b3046

Iseki, H., Taylor, B.D., Miller, M., 2006. The Effects of Out-of-Vehicle Time on Travel Behavior: Implications for Transit Transfers. California Department of Transportation Division of Research and Innovation, Sacramento, CA.

Johar, A., Jain, S.., Garg, P.., Gundaliya, P.., 2015. A study for Commuter Walk Distance from Bus Stops to Different Destination along Routes in Delhi. Eur. Transp.

Kittelson & Associates, Urbitran, LKC Consulting Services, MORPACE International, Queensland University of Technology, Nakanishi, Y., 2003. A guidebook for developing a transit performance- measurement system. TCRP Rep. 88.

Lesley, L., 2001. Generalised Costs and the Value of Time as a Method of Patronage Forecasting. Acta Tech. Jaurinensis 2, 57–68.

Litman, T., 2005. Impact of Rail Transit on the Performance of a Transport System. Transp. Res. Rec. 1930 23–29.

Lund, H., Cervero, R., Willson, R.W., 2004. Travel Characteristics of Transit-Oriented Development in California. Report, The University of California Transportation Center, Berkeley.

Mamun, S. Al, Lownes, N.E., 2011. A Composite Index of Public Transit Accessibility. J. Public Transp. 14, 69–87.

Mavoa, S., Witten, K., McCreanor, T., O'Sullivan, D., 2012. GIS based destination accessibility via public transit and walking in Auckland, New Zealand. J. Transp. Geogr. 20, 15–22. doi:10.1016/j.jtrangeo.2011.10.001

Mclntosh, J.R., Newman, P., Glazebrook, G., 2013. Why fast Trains Work: An assessment of a fast regional rail sysem in Perth, Australia. J. Transp. Technol. 3, 37–47.

Mohan, D., Tiwari, G., 2000. Mobiliy, Environment and Safety in Megacities- Dealing with a Complex Future. IATSS Res. 24, 39–46.

Newman, P., Kenworthy, J., 2015. The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning. Island Press, Washington D.C.

Parwez, A., 2013. Pricing & fare fixation in public transport BMTC - A case study. Bangalore Metropolitan Transport Corporation, Bangalore.

Polzin, S., Pendyala, R., Navari, S., 2002. Development of time-of-day–based transit accessibility analysis tool. J. Transp. Res. Board 1799, 35–41.

Ramirez, A., Seneviratne, P., 1996. Transit route design applications using Geographic Information Systems. Transp. Res. Rec. 1305 123–139.

RITES, 2011. Comprehensive Traffic & Transportation plan for Bengaluru. Report for Karnataka Urban Infrastructure Development and Finance Corporation, Bengaluru.

Rood, T., 1997. Local Index of Transit Availability- An Implementation Manual. Report for Local Government Commission, Sacramento, California.

Ryus, P., Ausman, J., Teaf, D., Cooper, M., Knoblauch, M., 2000. Development of Florida's transit level-of-service indicator. Transp. Res. Rec. 1731 123–129.

Schoon, J.G., McDonald, M., Lee, A., 1999. Accessibility indices: Pilot study and potential use in strategic planning. Transp. Res. Rec. 1685 29–38.

Tiwari, G., 2011. Key Mobility Challenges in Indian Cities, in: International Transport Forum. 18-20 May, Leipzig, Germany.

Topalovic, P., Carter, J., Topalovic, M., Krantzberg, G., 2012. Light Rail Transit in Hamilton: Health, Environmental and Economic Impact Analysis. Soc. Indic. Res. 108, 329–350. doi:10.1007/s11205-012-0069-x

Van Exel, N.J.A., Rietveld, P., 2010. Perceptions of public transport travel time and their effect on choice-sets among car drivers. J. Transp. Land Use 2, 75–86. doi:10.5198/jtlu.v2i3.15

Yigitcanlar, T., Sipe, N., Evans, R., Pitot, M., 2007. A GIS-based land use and public transport accessibility indexing model. Aust. Plan. 44, 30–37. doi:10.1080/07293682.2007.9982586

Zhao, F., Chow, L.-F., Li, M.-T., Gan, A., Ubaka, I., 2003. Forecasting Transit Walk Accessibility : A Regression Model Alternative to the Buffer. J. Transp. Res. Board. 1835, 34–41. doi:http://dx.doi.org/10.3141/1835-05

Zhao, F., Li, M.-T., Chow, L.-F., Gan, A., Shen, D.L., 2002. FSUTMS Mode Choice Modeling : Factors Affecting Transit Use and Access. Report no: NCTR 392-07, 416-03, National Center For Transit Research, University of South Florida

12 Bibliography

Advani M and Tiwari G (2006a) Bicycle – As a feeder mode for bus service. In: VELO MONDIAL conference, Cape Town, South Africa, pp. 1–8.

Advani M and Tiwari G (2006b) Bicycle - As a feeder mode for bus services. In: VELO MONDIAL conference, 5-10 March, Cape Town, South Africa.

Ahluwalia IJ, Kanbur R and Mohanty PK (2014) Urbanisation in India: Challenges, Opportunities and the Way Forward. SAGE Publication, India.

Alshalalfah B and Shalaby A (2005) Relationship between walk access distance to transit Socioeconomic, demographic and transit service characteristics. In: 84th Annual Meeting of Transportation Research Record, January 9–13, Washingon D.C.

Arora A and Tiwari G (2007) A Handbook for Socio-economic Impact Assessment (SEIA) of Future Urban Transport (FUT) Projects. Transportation Research and Injury Prevention Program (TRIPP), Indian Institute of Technology, New Delhi.

Arrington G. and Cervero R (2008) Effect of TOD on Housing, Parking, and Travel. Washington D.C.

Atkinson R (2000) Measuring Gentrification and Displacement in Greater London. Urban Studies, 37(1), 149–165.

Balya MI, Katti BK and Saw K (2016) Spatial Transit Accessibility Modeling of Indian Metropolitan City in Gis Environment. International Journal for Traffic and Transport Engineering, 6(1), 51–62.

Bangalore Housing Department (2009) Karnataka Housing and Habitat Policy. Report, Government of Karnataka.

Bangalore Metropolitan Rail Corporation Limited (2016) Available from: www.bmrc.co.in.

Bangalore Metropolitan Transport Corporation Limited (2015) Available from: mybmtc.com.

Belzer D, Bernstein S, Gorewitz C, et al. (2006) Preserving and Promoting Diverse Transit-Oriented Neighborhoods. Report, Center for Trnasit Oriented Development: A

collaboration of the Center for Neighborhood Technology, Reconnecting America, and Strategic Economics.

Benson N (2010) A Tale of Two Cities: Examining the Success of Inclusionary Zoning Ordinances in Montgomery County, Maryland and Boulder, Colorado. Journal of Gender, Race & Justice, 13(3), 753–777.

Bertolini L and Spit T (1998) Cities on Rail. Spon Press, London.

Bhat C, Bricka S, Mondia J la, et al. (2006) Metropolitan Area Transit Accessibility Analysis tool. Report, National Center for Transportation Research, University of South Florida. Report no: 0-5178-P3.

Bonnie Gee Yosick llc (2009) Housing and Transportation Cost Study. Report for City of Portland Bureau of Planning and Sustainability, Portland.

Booz & Company (2011) Integrating Australia's Transport Systems : A Strategy for an Efficient Transport Future. Infrastructure partnership Australia.

Bourne LS (1993) The Myth and Reality of Gentrification : A Commentary on Emerging Urban Forms. 30(1), 183–189.

Brown KD (2001) Expanding Affordable Housing Through Inclusionary Zoning : Lessons from the Washington Metropolitan Area. The Brookings Institution Center on Urban and Metropolitan Policy, Washington, DC.

Bruhat Bangalore Mahanagara Palike (2015) Available from: bbmp.gov.in.

Bruton MJ (1985) Introduction to transportation planning. Hutchinson, London.

Calavita N, Grimes K and Mallach A (1997) Inclusionary housing in California and New Jersey: A comparative analysis. Housing Policy Debate, 8(1), 109–142, Available from: http://www.tandfonline.com/doi/abs/10.1080/10511482.1997.9521249.

Center for Transit-Oriented Development (2009) Mixed-Income Housing Near Transit: Increasing Affordability With Location Efficiency. Washington D.C, Available from: tod-201-mixed-income-housing-near-transit-increasing-affordability-with-location-efficiency.

Cervero R (1993) Ridership Impacts of Transit-Focused Development in California. The University of California Transportation Center, Berkeley.

Cervero R (1994) Transit-based housing in California: evidence on ridership impacts. Transport Policy, 1(3), 174–183, Available from: http://linkinghub.elsevier.com/retrieve/pii/0967070X94900132.

Cervero R (2007) Transit-oriented development's ridership bonus: a product of self-selection and public policies. Environment and Planning A, 39(9), 2068–2085, Available from: http://www.envplan.com/abstract.cgi?id=a38377 (accessed 22 April 2015).

Cervero R (2010) Transit Transformations: Private Financing and Sustainable Urbanism in Hong Kong and Tokyo. In: Ascher W and Krupp C (eds), Physical Infrastructure Development: Balancing the Growth, Equity and Environmental Imperatives, New York: Palgrave Macmillan, pp. 165–185.

Cervero R (2011) State Roles in Providing Affordable Mass Transport Services for Low - Income Residents. In: International Transportation Forum, 25- 27 May, Leipzig, Germany.

Cervero R and Day J (2008) Suburbanization and transit-oriented development in China. Transport Policy, 15(5), 315–323.

Cervero R and Kockelman K (1997) Travel Demand and the 3Ds : Density, Diversity, and Design. Pergamon, 2(3), 199–219.

Cervero R and Murakami J (2009) Rail and Property Development in Hong Kong: Experiences and Extensions. Urban Studies, 46(10), 2019–2043.

Cervero R, Chapple K, Landis J, et al. (2006) MAKING DO: How Working Families in Seven U.S. Metropolitan Areas Trade Off Housing Costs and Commuting Times. Washington, DC: Center for Housing Policy, 2006.

Chapple K (2009) Mapping Susceptibility to Gentrification : The Early Warning Toolkit. Berkeley, CA: Center for Community Innovation.

Chapple K (2014) Planning Sustainable Cities and Regions: Towards More Equitable Development. Routledge (ed.).

Chapple K, Wegmann J, Nemirow A, et al. (2012) Yes in My Backyard: Mobilizing the Market for Secondary Units. Berkeley, CA: Center for Community Innovation, Available from: https://escholarship.org/uc/item/6fz8j6gx.

Chatman DG (2013) Does TOD Need the T? Journal of the American Planning Association, 79(1), 17–31, Available from: http://www.tandfonline.com/doi/abs/10.1080/01944363.2013.791008 (accessed 2 May 2014).

Chauhan V, Suman HK and Bolia NB (2016) Binary Logistic Model for Estimation of Mode Shift into Delhi Metro. The Open Transportation Journal, 10(1), 124–136, Available from: http://benthamopen.com/ABSTRACT/TOTJ-10-124.

Chava J and Newman P (2016) Stakeholder Deliberation on Developing Affordable Housing Strategies: Towards Inclusive and Sustainable Transit Oriented Developments. Sustainability, 8(10).

Chava J, Newman P and Tiwari R (2016a) Gentrification in New Build and Old Build Transit Oriented Developments: The Case of Bangalore. Curtin University Sustainability Policy Institute, Curtin University, Perth, WA.

Chava J, Newman P and Tiwari R (2016b) Gentrification of station areas and its impact on transit ridership. Curtin University, Perth, WA.

Chava J, Newman P and Tiwari R (2016c) Transit Accessibility and Affordability Index: A tool to evaluate transit quality. Curtin University, Perth, WA.

Curtis C, Scheurer J and Mellor R (2012) Spatial Network Analysis for Multimodal Urban Transport Systems (SNAMUTS). Report for European Cooperation in Science and Technology.

Danyluk M and Ley D (2007) Modalities of the New Middle Class: Ideology and Behaviour in the Journey to Work from Gentrified Neighbourhoods in Canada. Urban Studies, 44(11), 2195–2210, Available from: http://usj.sagepub.com/cgi/doi/10.1080/00420980701520277 (accessed 14 July 2014).

Davidson M (2007) Gentrification as global habitat: a process of class formation or corporate creation? Transactions of the Institute of British Geographers, 32(4), 490–506, Available from: http://doi.wiley.com/10.1111/j.1475-5661.2007.00269.x.

Davidson M and Lees L (2005) New-build gentrification and London's riverside renaissance. Environment and Planning A, 37, 1165–1190.

Dominie W (2012) Is Just Growth Smarter Growth ? The effect of Gentrification on Transit Ridership and Driving in Los Angele's transit station area Neighborhood. University of California, Berkley.

Dziauddin MF (2009) Measuring the Effects of the Light Rail Transit System on House Price in the Klang Valley, Malaysia. Thesis (PhD), Newcastle University.

Fan Y and Guthrie A (2012) Winners or Losers. Transportation Research Record: Journal of the Transportation Research Board, 2276, 89–100, Available from: http://trb.metapress.com/openurl.asp?genre=article&id=doi:10.3141/2276-11 (accessed 11 April 2014).

Feinstein BD and Allen A (2008) Article Community Benefits Agreements with Transit Agencies : Neighborhood Change Along Boston's Rail Lines and a Legal Strategy for Addressing Gentrification. Transportation law Journal, 38(85), 85–114.

Freeman L and Braconi F (2004) Gentrification and Displacement. Journal of the American Planning Association, 70(1), 39–52.

Fu L and Xin Y (2007) A New Performance Index for Evaluating Transit Quality of Service. Journal of Public Transportation, 10(3), 47–69.

Geofabrik (2015) Available from: download.geofabrik.de (accessed 10 November 2015).

German R (2007) Lecture Notes on Generalized Linear Models. Available from: http://data.princeton.edu/wws509/notes/.

Ghertner DA (2014) India's urban revolution: geographies of displacement beyond gentrification. Environment and Planning A, 46(7), 1554–1571, Available from: http://epn.sagepub.com/lookup/doi/10.1068/a46288 (accessed 11 May 2016).

Glass R (1964) Introduction: Aspects of Change. In: London : MacGibbon & Kee: Macgibbon & Kee.

Goel R and Tiwari G (2016) Access-egress and other travel characteristics of metro users in Delhi and its satellite cities. IATSS Research, The Authors, 39(2), 164–172, Available from: http://dx.doi.org/10.1016/j.iatssr.2015.10.001.

Gomez A and Echenique L (2007) Affordability of Public Transport: A Methodological Clarification. University of Las Palmas of Grand Canary.

Government of Karnataka (2009) Amendment to the zoning regulations of master plan of Bangalore. UDD 93 MNJ 2008, India.

Government of South Australia (2015) Community Engagement Handbook: A Model Framework for leading practice In Local Government in South Australia.

Grube-cavers A and Patterson Z (2015) Urban Rapid Rail Transit and Gentrification in Canadian Urban Centres – A Survival Analysis Approach. Urban studies, 50(1), Available from: https://www.cirrelt.ca/DocumentsTravail/CIRRELT-2013-06.pdf.

Guerra E, Cervero R and Tischler D (2011) The Half-Mile Circle: Does It Best Represent Transit Station Catchments? Report, Institute of Transportation Studies, University of California, Berkeley.

Hackworth J and Smith N (2001) The changing state of gentrification. Tijdschrift voor Economische en Sociale Geografie, 92(4), 464–477, Available from: http://doi.wiley.com/10.1111/1467-9663.00172.

Hartz-Karp, J., Newman P (2006) (2006) The Participative Route to Sustainability. In: Paulin S (ed.), Communities Doing it for Themselves: Creating Space for Sustainability, University of Western Australia Press, Perth.

Hartz-Karp J (2005) A case study in deliberative democracy: Dialogue with the city. Journal of Public Deliberation, 1(1), 1–15.

Hartz-karp J (2007) How and Why Deliberative Democracy Enables Co-Intelligence and Brings Wisdom to Governance How and Why Deliberative Democracy Enables Co-

Intelligence and. Journal of Public Deliberation, 3(1), Available from: http://www.publicdeliberation.net/jpd/vol3/iss1/art6.

Hartz-Karp J, Gollagher M and Weymouth R (2013) Sustainability through deliberative Democracy. Workbook, Curtin University Sustainability Policy Institute, Perth.

He S (2010) New-Build Gentrification in Central Shanghai: Demographic Changes and Socioeconomic Implications. Population, Space and Place, 361(July 2009), 345–361.

He S (2012) Two waves of gentrification and emerging rights issues in Guangzhou, China. Environment and Planning A, 44(12), 2817–2833, Available from: http://epn.sagepub.com/lookup/doi/10.1068/a44254 (accessed 11 May 2016).

Hendricks SJ, Winters P, Wambalaba F, et al. (2005) Impacts of Transit Oriented Development On Public Transportation Ridership. Report, Center for Urban Transport reserach, University of South Florida, Tempa: National Research council, Washington, D.C.

Hillman R and Pool G (1997) GIS-based Innovations for modeling public transport accessibility. Traffic Engineering and Control, 38(10), 554–559.

Horner MW and Murray AT (2004) Spatial representation and scale impacts in transit service assessment. Environment and Planning B: Planning and Design, 31(5), 785–797, Available from: http://www.envplan.com/abstract.cgi?id=b3046 (accessed 17 October 2014).

International Association for Public Participation (2016) Available from: www.iap2.org.au (accessed 25 April 2016).

Iseki H, Taylor BD and Miller M (2006) The Effects of Out-of-Vehicle Time on Travel Behavior: Implications for Transit Transfers. California Department of Transportation Division of Research and Innovation, Sacramento, CA, Available from: http://164.67.121.38/research/EPIC/Appendix A.pdf.

Jillella S, Matan A and Newman P (2015) Participatory Sustainability Approach to Value Capture-Based Urban Rail Financing in India through Deliberated Stakeholder Engagement. Sustainability, 7(7), 8091–8115, Available from: http://www.mdpi.com/2071-1050/7/7/8091/ (accessed 19 August 2015).

Johar A, Jain S., Garg P., et al. (2015) A study for Commuter Walk Distance from Bus Stops to Different Destination along Routes in Delhi. european transport, (59).

Jones Lang Lasalle (2012) Affordable Housing in India: An Inclusive Approch to Sheltering the Bottom of the Pyramid. Report, New Delhi.

Chava J, Newman P and Tiwari R (2016) Gentrification of station areas and its impact on transit ridership. Curtin University Sustainability Policy Institute, Curtin University, Perth, WA.

Kahn ME (2007) Gentrification Trends in New Transit-Oriented Communities : Evidence from 14 Cities That Expanded and Built Rail Transit Systems. Real Estate Economics, 35, 155–182.

Katz B and Sawyer N (2003) Rethinking Local Affordable Housing Strategies: Lessons From 70 Years of Policy and Practice. The Brookings Institution Center on Urban and Metropolitan Policy and The Urban Institute, Washington, DC.

Kittelson & Associates, Urbitran, LKC Consulting Services, et al. (2003) A guidebook for developing a transit performance- measurement system. TCRP report 88, TRB, Washington, D.C., Available from: http://gulliver.trb.org/publications/tcrp/tcrp_report_88/ Guidebook.pdf.

Knaap GJ, Ding C and Hopkins LD (2001) Do Plans Matter?: The Effects of Light Rail Plans on Land Values in Station Areas. Journal of Planning Education and Research, 21(1), 32–39, Available from: http://jpe.sagepub.com/cgi/doi/10.1177/0739456X0102100103 (accessed 27 May 2014).

Kniech BR and Pollack M (2010) Making affordable Housing at Transit a ReaBest Practices in Transit Agency Joint Development Affordable Housing Best Practices in Transit Agency Joint Development. Report, FRESC: Good Jobs, Strong Communities and Enterprise researched.

Kosareva N and Tumanov a. (2008) Assessing Housing Affordability in Russia. Problems of Economic Transition, 50(10), 6–29, Available from: http://mesharpe.metapress.com/openurl.asp?genre=article&id=doi:10.2753/PET1061-1991501001 (accessed 5 May 2014).

Kushto ER and Schofer JL (2008) Travel and Transportation Impacts of Urban Gentrification: Chicago, Illinois Case Study. Northwestern University, Evanston, Illinois.

Land M Van Der, Curley A and Eijk G Van (2012) Gentrification and Neighbourhood Change. In: International Encyclopedia of Housing and Home, Elsevierr Ltd., pp. 275–279, Available from: http://dx.doi.org/10.1016/B978-0-08-047163-1.00594-4.

Lees L, Slater T and Wyly EG (2008) Gentrification. Routledge, New York: New York: Routledge.

Lesley L (2001) Generalised Costs and the Value of Time as a Method of Patronage Forecasting. Acta Technica Jaurinensis, 2(1), 57–68.

Levy DK, Comey J and Padilla S (2006) Keeping the Neighborhood Affordable: A Handbook of Housing Strategies for Gentrifying Areas. Report, The urban Institute, Washington, D.C.

Lierop D van, Maat K and El-Geneidy A (2016) Talking TOD : Learning about Transit-Oriented Development in the United States, Canada , and the Netherlands. Journal of Urbanism, (May 2016), 1–31.

Lin J (2002) Gentrification and Transit in Northwest Chicago. Journal of Transport Research Forum, 56(4), 175–191.

Litman T (2005) Impact of Rail Transit on the Performance of a Transport System. Transportation Research Record 1930, Transportation Research Board, 23–29.

Litman T (2013a) Affordable-Accessible Housing In A Dynamic City Why and How To Increase Affordable Housing Development In Accessible Locations. Report, Victoria Transport Policy Institute, Canada.

Litman T (2013b) Evaluating Transportation Equity Guidance For Incorporating Distributional Impacts in Transportation Planning. World Transport Policy &Practice, 8(2), 50–65.

Litman T and Brenman M (2012) A New Social Equity Agenda For Sustainable Transportation. Report, Victoria Transport Policy Institute, Canada.

Lo HK, Tang S and Wang DZW (2008) Managing the accessibility on mass public transit : The case of Hong Kong. Journal of Transport and Land Use, 2(Fall), 23–49.

Loukaitou-Sideris A (2010) A New-found Popularity for Transit-oriented Developments? Lessons from Southern California. Journal of Urban Design, 15(1), 49–68, Available from: http://www.tandfonline.com/doi/abs/10.1080/13574800903429399 (accessed 16 April 2014).

Lund H (2006) Reasons for Living in a Transit-Oriented Development, and Associated Transit Use. Journal of the American Planning Association, 72(3), 357–367.

Lund H, Cervero R and Willson RW (2004) Travel Characteristics of Transit-Oriented Development in California. Report, The University of California Transportation Center, Berkeley.

Machell E, Reinhalter T and Chapple K (2009) Building Support for Transit-Oriented Development : Do Community-Engagement Toolkits Work ? Berkeley, CA: Center for Community Innovation.

Mamun S (2011) Public Transit Accessibility and Need Indices : Approaches for Measuring Service Gap. University of Connecticut.

Mamun S Al and Lownes NE (2011) A Composite Index of Public Transit Accessibility. Journal of Public Transportation, 14(2), 69–87.

Manaugh K (2013) Incorporating issues of social justice and equity into transportation planning and policy. PhD thesis, School of Urban planning, McGill University, Canada.

Mavoa S, Witten K, McCreanor T, et al. (2012) GIS based destination accessibility via public transit and walking in Auckland, New Zealand. Journal of Transport Geography, Elsevier Ltd, 20(1), 15–22, Available from: http://linkinghub.elsevier.com/retrieve/pii/S0966692311001529 (accessed 26 October 2014).

McIntosh J, Turbka R and Newman P (2013) Can Value Capture work in a car dependent city? Willingness to pay for transit access in Perth, Western Australia. Transportation Research - Part A, 67, 320–339.

McIntosh J, Newman P and Glazebrook G (2013) Why Fast Trains Work: An Assessment of a Fast Regional Rail System in Perth, Australia. Journal of Transportation Technologies, 3(2), 37–47, Available from: http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/jtts.2013.32A005 (accessed 28 March 2016).

Mckibbin M (2011) The influence of the built environment on mode choice – evidence from the journey to work in Sydney. In: Australasian Transport Research Forum 2011, Adelaide, Australia, pp. 1–12.

Mclntosh JR, Newman P and Glazebrook G (2013) Why fast Trains Work: An assessment of a fast regional rail sysem in Perth, Australia. Journal of Transportation Technologies, 3(2), 37–47, Available from: http://www.scirp.org/journal/PaperDownload.aspx?DOI=10.4236/jtts.2013.32A005 (accessed 28 March 2016).

Ministry of Housing and Urban Poverty Allevation (2009a) Guidelines for affordable housing in partnership. Government of India, New Delhi.

Ministry of Housing and Urban Poverty Allevation (2009b) Guidelines for Interest Subsidy Scheme for Housing the Urban Poor (ISHUP). New Delhi, Available from: http://mhupa.gov.in/w_new/ISHUPGuidelines.pdf.

Ministry of Housing and Urban Poverty Allevation (2013) Affordable housing in partnership Scheme guidelines. Government of India, New Delhi, Available from: http://mhupa.gov.in/W_new/AHP_23_09_2013.pdf.

Ministry of Housing and Urban Poverty Alleviation (2007) National Urban Housing and Habitat Policy. Report, Government of India, New Delhi, Available from: http://mhupa.gov.in/policies/duepa/HousingPolicy2007.pdf.

Ministry of Urban Development (2012) Innovative financing of Metro Rail Projects. Government of India.

Mixed-Income Transit-Oriented Development (2016) Available from: www.mitod.org (accessed 31 May 2015).

Mohan D and Tiwari G (2000) Mobiliy, Environment and Safety in Megacities- Dealing with a Complex Future. IATSS Research, 24(1), 39–46.

Mu R and Jong M de (2012) Establishing the conditions for effective transit-oriented development in China: the case of Dalian. Journal of Transport Geography, Elsevier Ltd, 24, 234–249, Available from: http://linkinghub.elsevier.com/retrieve/pii/S0966692312000592 (accessed 20 November 2013).

Muley DS (2011) Evaluating the Transport Impacts of Transit Oriented Developments (TODs). PhD thesis, School of Urban Development, Faculty of Built Environment & Engineering, Queensland University of Technology.

Murphy L (2008) Third-wave Gentrification in New Zealand: The Case of Auckland. Urban Studies, 45(12), 2521–2540, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097106 (accessed 11 May 2016).

National Urban Transport Policy (2001) Report, Directorate of Urban Land Transport, New Delhi.

Neill PO, Johnston K, Phibbs P, et al. (2008) Housing Affordability Literature Review and Affordable Housing Program Audit. Urban Research Center, University of Western Sydney, Sydney, Available from: www.uws.edu.au/__data/assets/pdf_file/0004/164623/landcom_report_2008-07-21.pdf.

Nelson AC (2003) Top Ten State and Local Strategies to Increase Affordable Housing Supply. Housing Facts and Findings, 5(1).

Nemirow A and Chapple K (2012) Yes , But Will They Let Us Build ? The Feasibility of Secondary Units in the East Bay. IURD Working Paper, Berkeley, CA: Institute of Urban & Regional Development.

Newman K and Wyly E (2006) The right to stay put, revisited: Gentrification and resistance to displacement in New York city. Urban Studies, 43(1), 23–57, Available from: http://usj.sagepub.com/cgi/doi/10.1080/00420980500388710.

Newman P (2014) Density, the Sustainability Multiplier: Some Myths and Truths with Application to Perth, Australia. Sustainability, 6(9), 6467–6487, Available from: http://www.mdpi.com/2071-1050/6/9/6467/.

Newman P and Kenworthy J (1989) Cities and Automobile Dependence: An International Sourcebook. Gower, Aldershot, UK.

Newman P and Kenworthy J (1999) Sustainability and Cities: Overcoming Automobile Dependence. Island Press, Washington, DC.

Newman P and Kenworthy J (2015) The End of Automobile Dependence How Cities are Moving Beyond Car-Based Planning. Washington D.C: Island Press.

Newman P and Matan A (2013) Green Urbanisam in Asia: The Emerging Green Tigers. Ying LX (ed.), World Scientific.

Nordregio, OIR and TU Delft (2016) Transit-oriented development and sustainable urban planning. Report for JPI Urban Europe CASUAL project.

Ogra A and Ndebele R (2014) The Role of 6Ds : Density, Diversity , Design , Destination , Distance , and Demand Management in Transit Oriented Development (TOD). In: Neo-International Conference on Habitable Environments, San Diego, USA, pp. 539–546.

Parking Spaces / Community Places: Finding the Balance through Smart Growth Solutions (2006) Report, EPA's Development, Community, and Environment Division, U.S. Environmental Protection Agency, Washington, DC.

Parwez A (2013) Pricing & fare fixation in public transport BMTC - A case study. Bangalore Metropolitan Transport Corporation, Bangalore.

Planning Commission (2013) Recommendations of Working Group on Urban Transport for 12th Five Year Plan. New Delhi.

Pojani D and Stead D (2016) A Critical Deconstruction of the Concept of Transit Oriented Development (TOD) Dorina Pojani, Dominic Stead. In: SCHRENK M, POPOVICH V V, ZEILE P, et al. (eds), Real corp, Hamburg, Germany, pp. 829–833.

Pollack S, Bluestone B and Billingham C (2010) Maintaining Diversity In America's Transit-Rich Neighborhoods: Tools for Equitable Neighborhood Change. Dukis Center for Urban and Regional policy, Northeastern University.

Polzin S, Pendyala R and Navari S (2002) Development of time-of-day–based transit accessibility analysis tool. Journal of Transportation Research Board, TRB, National Research Council, Washington D.C., 1799, 35–41.

Pucher J and Renne JL (2003) Socioeconomics of Urban Travel: Evidence from the 2001NHTS. Transportation Quarterly, 57(3), 49–77.

Quigley L (2010) Preserving Affordable Housing Near Transit: Case Studies from Atlanta, Denver, Seattle and Washington, D.C.

Ramirez A and Seneviratne P (1996) Transit route design applications using Geographic Information Systems. Transportation Research Record 1305, 123–139.

Rangwala L, Mathews R and Sridhar S (2014) Shifting Discourse About Transit-Oriented Development in Mumbai, India. Transportation Research Record: Journal of the Transportation Research Board, 2451, 60–67, Available from: http://trrjournalonline.trb.org/doi/abs/10.3141/2451-07.

Reconnecting America (2013) An Equitable TOD Typology for the Atlanta Region.

Reconnecting America (2014) User's Guide TOD Classification Tool.

Reconnecting America, Center for Community Innovation and Non-Profit Housing Association of Northern California (2007) Transit-Oriented for All : The Case for Mixed-Income Transit-Oriented Communities in the Bay Area. Berkeley, CA: Center for Community Innovation, Available from: http://communityinnovation.berkeley.edu/Publications.

Renne JL (2014) TOD Index TM. Report, University of New Orleans, Available from: www.TODindex.com.

Rérat P, Söderström O, Piguet E, et al. (2010) From Urban Wastelands to New-Build Gentrification : The Case of Swiss Cities. POPULATION, SPACE AND PLACE, 10(16), 429–442.

Rérat P, Söderström O and Piguet E (2010) New Forms of Gentrification: Issues and Debates. POPULATION, SPACE AND PLACE, 10(16), 335–343.

RITES (2011) Comprehensive Traffic & Transportation plan for Bengaluru. Report for Karnataka Urban Infrastructure Development and Finance Corporation, Bengaluru.

RITES (2012) Implementation of Commuter Rail System for Bangalore Draft Report. Report for Directorate of Urban Land Transport, Government of Karnataka, Bengaluru.

Rood T (1997) Local Index of Transit Availability- An Implementation Manual. Report for Local Government Commission, Sacramento, California.

Ryus P, Ausman J, Teaf D, et al. (2000) Development of Florida's transit level-of-service indicator. Transportation Research Record 1731, 123–129.

Schoon JG, McDonald M and Lee A (1999) Accessibility indices: Pilot study and potential use in strategic planning. Transportation Research Record 1685, 29–38.

Shoemaker D (2006) Tools for Mixed-Income TOD. Report for Center for Transit Oriented Development, Available from: www.reconnectingamerica.org/assets/Uploads/tools.pdf.

Smith N (1982) Gentrification and Uneven Development. Economic Geography, JOUR, Clark University, 58(2), 139–155, Available from: http://www.jstor.org/stable/143793.

Smith N (1996) The New Urban Frontier: Gentrification and the Revanchist City. London and New York.: Routledge.

Song W and Zhu X (2011) Gentrification in Urban China under Market Transformation. International Journal of Urban Sciences, 14(2), 152–163, Available from: http://www.tandfonline.com/doi/abs/10.1080/12265934.2010.9693673 (accessed 11 May 2016).

Suzuki H, Iuchi K and Cervero R (2013) Transforming cities with transit: Transit and Land-Use Integration for Sustainable Urban Development. Washington DC: World Bank.

The city of Atlanta (2005) Beltline Tax Allocation District Ordinance. 05-O-1733, Georgia.

Tiwari G (2011) Key Mobility Challenges in Indian Cities. In: International Transport Forum, 18-20 May, Leipzig, Germany.

Tiwari G and Jain H (2008) bicle in india-IUT-himani.o.pdf. IUT Journal, 59–68.

Topalovic P, Carter J, Topalovic M, et al. (2012) Light Rail Transit in Hamilton: Health, Environmental and Economic Impact Analysis. Social Indicators Research, 108(2), 329–350, Available from: http://link.springer.com/10.1007/s11205-012-0069-x (accessed 10 June 2014).

Tsietsi Monare P, Kotzé N and Morton McKay T (2014) A second wave of gentrification: The case of Parkhurst, Johannesburg, South Africa. Urbani izziv, 25(Supplement), S108–S121, Available from: http://urbani-izziv.uirs.si/Portals/uizziv/papers/urbani-izziv-en-2014-25-supplement-008.pdf (accessed 11 May 2016).

Van Exel NJA and Rietveld P (2010) Perceptions of public transport travel time and their effect on choice-sets among car drivers. Journal of Transport and Land Use, 2(2005), 75–86.

Van Gent WPC (2013) Neoliberalization, Housing Institutions and Variegated Gentrification: How the 'Third Wave' Broke in Amsterdam. International Journal of Urban and Regional Research, 37(2), 503–522, Available from: http://doi.wiley.com/10.1111/j.1468-2427.2012.01155.x (accessed 11 May 2016).

Visser G and Kotze N (2008) The State and New-build Gentrification in Central Cape Town, South Africa. Urban Studies, 45(12), 2565–2593, Available from: http://usj.sagepub.com/cgi/doi/10.1177/0042098008097104 (accessed 31 March 2014).

Walker S (2013) The Handbook of Design for Sustainability. Illustrate. Walker S and Giard J (eds), A&C Black.

Wegmann J and Chapple K (2014) Hidden density in single-family neighborhoods: backyard cottages as an equitable smart growth strategy. Journal of Urbanism: International Research on Placemaking and Urban Sustainability, 7(3), 307–329, Available from: http://www.tandfonline.com/doi/abs/10.1080/17549175.2013.879453#.VPpF98aIlKo.

Weinberger R, Kaehny J and Rufo M (2010) U.S. Parking Policies : An Overview of Management Strategies. Report, Institute for Transportation and Development Policy, New York.

Wyly E. and Hammel DJ (1999) Islands of decay in seas of renewal: housing policy and the resurgence of gentrification. Housing Policy Debate, 10(4), 711–771.

Yan S, Delmelle E and Duncan M (2012) The impact of a new light rail system on single-family property values in Charlotte, North Carolina. Journal of Transport and Land Use, Available from: https://www.jtlu.org/index.php/jtlu/article/view/261.

Yigitcanlar T, Sipe N, Evans R, et al. (2007) A GIS-based land use and public transport accessibility indexing model. Australian Planner, 44(3), 30–37, Available from: http://www.tandfonline.com/doi/abs/10.1080/07293682.2007.9982586 (accessed 26 October 2014).

Zhao F, Li M-T, Chow L-F, et al. (2002) FSUTMS Mode Choice Modeling : Factors Affecting Transit Use and Access. Report no: NCTR 392-07, 416-03, National Center For Transit Research, University of South Florida.

Zhao F, Chow L-F, Li M-T, et al. (2003) Forecasting Transit Walk Accessibility : A Regression Model Alternative to the Buffer. Journal of Transportation Research Board., 1835, 34–41.

Zuk M, Bierbaum A, Chapple K, et al. (2015) Gentrification, Displacement, and the Role of Investment: A Literature Review. Federal Reserve Bank of San Francisco.

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13 Appendixes

Appendix –A: Household Survey

Curtin University	Structured Interviews through Questionnaire Survey **For Incorporating Equity in Public Transport Planning: Research profile 1**

INSTITUTION: Curtin University Sustainability Policy (CUSP) Institute

ADDRESS: CUSP, 209, Curtin University, Kent Street, Bentley, Perth, Western Australia 6102

RESEARCHER: Jyothi Chava

TITLE OF RESEARCH PROJECT: "Incorporating Equity in Public Transport Planning: The case of Bengaluru"

SURVEY TEAM: The survey team is from OMRC consulting, please cooperate with them. Confidentiality of data will be maintained and the data will be used for pure academic purpose**.**

HOUSEHOLD SURVEY PART I - SOCIO ECONOMIC AND HOUSING CHARACTERISTICS

1. Reference

Date: Surveyor name:

Address/ Door No.: Phone No:

Settlement Code: _____ (**1.** Apartment **2.** Old residential area 3. Slums)

2. Household Information (Socio-economic)

SI. No. (Tick Respondent)	Relation with head	Sex (M/F)	Age	Education qualification	Occupation	Government assistance	Vehicle ownership		Income
1	2	3	4	5	6	7	Type (8)	Age (9)	10
1 Head									
2									
3									
4									
5									

No	Codes	1	2	3	4	5	6	7	8	9
5	Education	Illiterate	<HSC	HSC	Course	UG	PG			
6	Occupation	Working class	self-employ	Accounts	Professional	Business Man	Home maker	Student	Retired	Unemployed
7	Gov. assistance	AAY Card	BPL Card	APL Card	Pension receiver	Fee waiver	Scholarship			
8	Vehicle type	Bicycle	2-Wheeler	Car						
10	Income (Lakhs in ₹)	0-1.5	1.5 - 3	3 - 5	5 -7.5	7.5 - 10	10 -15	15 – 20	Over 20	

3. Housing and Living Conditions

1	What is the tenure arrangement of the house you live in?	Own	Rented/leased	Shared
2	If it is own house, what is the approximate value of the property	Land Value INR _____	Building Value INR _____	
3	If it is Rented, What is the rent you pay for it?	INR_____ /Month		
4	If it is leased, what is the lease amount?	INR_____		
5	What is the percentage of annual increase in rental value?			
6	Tick and write the appropriate spaces in the house	Rooms _____ (no.)	Separate Kitchen Y/N	Floors_____ (no.)
7	What is the area of the house?	_____Sq.ft		
8	What is your property tax? (Tick and Write the appropriate value)	INR_____	No	
9	How long have you been staying in this house?	_____ Years		
10	What is the age of house?	_____ Years		
11	If you move in recently, reasons for choosing to live in TOD[1] (use codes below)			

[1] please refer the codes below

No	1	2	3	4	5	6	7	8
11	Type and Quality of housing	Cost of housing	Quality of Neighborhood	Access to shops , services	Access to transit	Access to Highway	Others (specify)	
II	Work	Education	Shopping	Social	Return to home			
III	Walk	Bicycle	Bus	LRT/Metro	shared bus/car	2-Wheeler	Auto	Car

Part II- Travel Diary

4. Travel Characteristics of Household Members

SI. No	Person 1	Trip 1	Trip 2	Trip 3	Trip 4
I	Time you left (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
II	Trip Purpose (use codes above)				
III	Means of Travel (use codes above)				
IV	Origin				
V	Destination				
VI	Arrival time at destination (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
VII	Length of the trip				
VIII	Total cost/fare for making the trip				
IX	Frequency of the particular trip per week				
X	Is there any alternative means of travel available for making the same trip				
XI	If you moved in recently, what was the means of travel for the same trip in your prior residence (codes)				
XII	If you are a Metro user, what was the means of travel prior to metro (codes)				
XIII	If you are a PT user, Access trip mode				
XIV	If you are a PT user, Egress trip mode				
XV	If the metro is fully developed willing to use metro for the same trip (Yes/No)				
XVI	Please mark three reasons for not choosing metro (use codes above)				
XVII	Is there any facilities provided by employer/education provider (mark anyone)	1. Free parking	2. Cab/Bus service	3. PT concession	

XVI	Lack of availability/ accessibility of the metro	time-consuming LMC	Expensive LMC	Unsafe LMC	Lack of feeder services			

SI. No	Person 2	Trip 1	Trip 2	Trip 3	Trip 4
I	Time you left (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
II	Trip Purpose (use codes above)				
III	Means of Travel (use codes above)				
IV	Origin				
V	Destination				
VI	Arrival time at destination (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
VII	Length of the trip				
VIII	Total cost/fare for making the trip				
IX	Frequency of the particular trip per week				
X	Is there any alternative means of travel available for making the same trip				
XI	If you moved in recently, what was the means of travel for the same trip in your prior residence (codes)				
XII	If you are a Metro user, what was the means of travel prior to metro (codes)				
XIII	If you are a PT user, Access trip mode				
XIV	If you are a PT user, Egress trip mode				
XV	If the metro is fully developed willing to use metro for the same trip (Yes/No)				
XVI	Please mark three reasons for not choosing metro (use codes above)				
XVII	Is there any facilities provided by employer/education provider (mark anyone)	1. Free parking	2. Cab/Bus service	3. PT concession	

SI. No	Person 3	Trip 1	Trip 2	Trip 3	Trip 4
I	Time you left (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
II	Trip Purpose (use codes above)				
III	Means of Travel (use codes above)				
IV	Origin				
V	Destination				
VI	Arrival time at destination (circle AM or PM)	AM/PM	AM/PM	AM/PM	AM/PM
VII	Length of the trip				
VIII	Total cost/fare for making the trip				
IX	Frequency of the particular trip per week				
X	Is there any alternative means of travel available for making the same trip				
XI	If you moved in recently, what was the means of travel for the same trip in your prior residence (codes)				
XII	If you are a Metro user, what was the means of travel prior to metro (codes)				
XIII	If you are a PT user, Access trip mode				
XIV	If you are a PT user, Egress trip mode				
XV	If the metro is fully developed willing to use metro for the same trip (Yes/No)				
XVI	Please mark three reasons for not choosing metro (use codes above)				
XVII	Is there any facilities provided by employer/education provider (mark anyone)	1. Free parking	2. Cab/Bus service	3. PT concession	

Appendix –B: Metro user Survey

Curtin University	Structured Interviews through Questionnaire Survey **For Incorporating Equity in Public Transport Planning: Research profile 2**

INSTITUTION: Curtin University Sustainability Policy (CUSP) Institute

ADDRESS: CUSP, 209, Curtin University, Kent Street, Bentley, Perth, Western Australia 6102

RESEARCHER: Jyothi Chava

TITLE OF RESEARCH PROJECT: "Incorporating Equity in Public Transport Planning: The case of Bengaluru"

SURVEY TEAM: The survey team is from OMRC consulting, please cooperate with them. Confidentiality of data will be maintained and the data will be used for pure academic purpose**.**

1. Are you the resident of new build or old build developments (tick one)

   New build development ☐ Old build developments ☐

2. Gender (tick one)

   Male ☐ Female ☐

3. Occupation (tick one)

   Working class ☐ Self-employ ☐ Accounts ☐
   Professional ☐ Business man ☐ Student ☐
   Housewife ☐ Retired ☐ Unemployed ☐

4. What is your destination? please give address of the school/college/office/home/mar ket

   _____

5. What is the trip purpose (tick one)

   Work ☐ Education ☐ Shopping ☐

   Social ☐ Return to home ☐

6. How will you go from metro station to your destination (tick one)

   Walk ☐ Cycle ☐ Bus ☐ Auto ☐

   Rickshaw ☐ Car ☐ motorcycle/scooter ☐

7. Before metro how did you travel for this journey? (tick one)

   Walk ☐ Cycle ☐ Bus ☐ Auto ☐

   Rickshaw ☐ Car ☐ motorcycle/scooter ☐

8. Would you still make this trip if metro was not available? (tick one)

   Yes ☐ No ☐ May be ☐

Appendix –C: Population, Employment and School enrollment data for base and horizon year

Table 1: Population, Employment and School enrollment data for various years in each traffic analysis zone

Ward_ no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
1	HMT	33409	47837	59467	8857	20133	45765	1712	2452	3048
2	Jalahalli	41848	55139	65584	21084	26394	33043	13444	17714	21069
3	Yeshwantpura	51794	63125	71475	50329	63236	79454	21298	25958	29391
4	Mathikere-North	29569	34553	39317	8805	10154	11708	11212	13102	14908
5	Kodandarampura	28727	34553	39317	6063	7093	8298	2783	3347	3808
6	Dattatreya Temple	40817	44499	48189	13361	14517	15774	19267	21005	22747
7	Malleswaram	38961	46900	50790	60604	69195	79004	45562	54846	59395
8	Gayathrinagar	40328	42192	44349	2537	3846	5830	1176	1230	1293
9	Subramanyanagar	42458	45837	48181	2428	6220	15930	1617	1746	1835
10	Mahalakshmipuram	39531	43812	46053	7987	8621	9305	7711	8546	8983
11	Peenya Industrial Area	38161	43549	46927	85780	124426	180484	12647	14433	15552
12	Nandini Layout	40726	44367	48047	12489	13565	14735	1948	2122	2298
13	Geleyara Balaga Layout	47864	56757	62695	7857	8992	10291	9138	10836	11969
14	Nagapura	39313	48576	52345	4843	10192	21449	3064	3786	4079
15	Rajajinagar	39683	44949	48436	53555	59167	65368	59931	67883	73150
16	Kamalanagar	42532	45597	49379	11839	12756	13744	4228	4532	4908
17	Vrushabhavathinagar	31727	36724	39770	5746	6433	7202	2022	2341	2535
18	Kamakshipalya	32504	36724	39770	26919	29776	32937	5747	6494	7032
19	Basaweshwaranagar	31155	36887	39947	14705	16651	18854	17690	20945	22682
20	Shivanagar	30431	33897	37444	7780	8630	9573	6495	7235	7991
21	Industrial Town-West	25589	29478	32563	12922	14577	16444	4932	5682	6276

Ward_ no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
22	Sriramamandir	33356	35662	39393	7651	8314	9035	9445	10098	11155
23	Prakashnagar	37995	40535	44775	5262	5713	6201	2548	2719	3003
24	Bhashyam nagar	17167	19965	22054	2653	3007	3408	2738	3185	3518
25	Ramachandrapura	43821	47701	51147	11029	11915	12873	8948	9740	10444
26	Sevashrama	37363	43657	47278	2755	3099	3486	2457	2871	3109
27	Gandhinagar	38081	42706	46248	130013	174010	232896	31017	34784	37669
28	Chickpet	38159	43457	47061	26765	29724	33010	2969	3381	3661
29	Cottonpet	37861	38884	39669	5848	8066	11127	1973	2026	2067
30	S.K.R. Market	32899	33748	34429	142862	146148	149510	31863	32686	33346
31	Binnypet	32503	32906	33570	15643	15897	16156	4577	4634	4727
32	Kempapura Agrahara	41210	41811	42654	7730	7864	8001	6223	6313	6441
33	Vijayanagar	39870	40826	41650	48094	49156	50240	31803	32565	33222
34	RPC Layout (Hampi nagar)	29087	32427	34085	8415	9109	9861	7911	8820	9271
35	Marenahalli	42649	47892	51608	4575	6943	10536	3690	4144	4465
36	Thimmanahalli	46559	49811	52358	10942	12941	15305	9009	9638	10131
37	Amarjyothinagar	48599	55034	59010	4841	8767	15878	1797	2035	2182
38	Moodalapalya	46882	49005	53070	3186	4587	6606	1621	1695	1835
39	Chandra Layout	40577	42843	47325	9222	12797	17756	7258	7663	8465
40	Attiguppe	25266	28562	31550	5777	6455	7213	6634	7499	8284
41	Gali Anjaneyaswamy Temple	23306	27656	30549	6527	11005	18555	7232	8581	9479
42	Bapuji Nagara	17997	19783	21853	10388	12322	14614	12816	14089	15563
43	Padarayanapura	46967	52239	57704	7101	9505	12724	11900	13235	14620
44	Jagajivanramnagar	29770	34382	38738	4914	5606	6394	5273	6090	6862

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
45	Azadnagar	33178	37816	39750	5801	6349	6950	8796	10025	10538
46	Chamarajapet	23744	25211	26500	48132	50849	53719	30168	32032	33670
47	Dharmarayaswamy Temple	43223	50555	53140	35945	39856	44193	7730	9042	9504
48	Sudhamanagar	59933	63577	65510	5170	8995	15651	2655	2816	2902
49	Kempegowda nagar	44029	46686	48106	8652	9043	9453	6656	7058	7273
50	Vishweshwarapuram	40821	47457	49884	3016	4490	6686	6368	7404	7782
51	Basavanagudi	42577	49667	52207	31312	34672	38393	45879	53518	56255
52	Hanumanthanagar	36154	39333	42385	7663	8297	8984	7068	7689	8286
53	Srinagar	42419	50626	53746	12642	14230	16017	10772	12856	13649
54	Srinivasanagara	44071	50491	54408	3771	4190	4655	3764	4313	4647
55	Girinagar III Stage	20477	24278	26818	7749	8868	10149	8357	9908	10945
56	Banashankari II stage	13732	16185	17879	35312	40292	45975	24983	29446	32527
57	JP Nagar I, VI Phase	44418	49502	53608	18126	19913	21876	11694	13032	14113
58	Jayanagar IV, V	39287	43320	45535	55807	60081	64682	58931	64980	68303
59	Yediyur	35282	37987	39930	3301	4716	6736	4139	4457	4685
60	Jayanagar Complex, III Block	35210	37987	39930	1425	2422	4116	5012	5407	5684
61	Mavalli	41485	50639	54839	10254	11790	13555	11091	13538	14661
62	Siddapura	46035	50639	54839	6698	7310	7979	7656	8422	9120
63	Lakkasandra	41100	47060	50963	6089	8742	12551	6105	6991	7571
64	Gurappanapalya-East	40674	47060	50963	4057	6396	10084	7732	8946	9688
65	BTM Layout-North	41123	47060	50963	25445	28326	31533	12508	14313	15501
66	Madivala-East	56129	65959	71430	24794	27970	31553	14729	17309	18744
67	Koramangala-West	34923	43973	47620	62484	72964	85201	23680	29816	32289
68	Ejipura	36859	40016	43335	8617	9344	10131	5254	5704	6177

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
69	Neelasandra	35621	40016	43335	8821	9730	10732	9562	10742	11633
70	Shanthinagar	21165	24030	26023	16369	18151	20127	7673	8712	9435
71	Austin Town	22211	24030	26023	7403	8013	8674	7160	7746	8389
72	Domlur-North	38571	43346	46941	15902	17542	19352	3701	4159	4503
73	Jivanbima Nagar	21172	24610	26520	3312	4865	7148	3520	4091	4408
74	Jeevanbimanagar	22104	24610	26520	29636	32461	35556	11092	12350	13308
75	Jogupalya	41646	45596	47928	5062	5430	5825	7837	8581	9019
76	Richmond Town	30172	33757	36557	77021	84781	93322	28418	31795	34432
77	Sampangiramnagar	32679	33757	36557	44789	47372	50104	23379	24150	26154
78	Vasanthnagar	26194	30586	33786	27143	30827	35011	13734	16037	17715
79	Shivajinagar	27085	30586	33786	63638	71076	79383	25867	29211	32267
80	Bharathinagar	47752	55869	61714	3847	5178	6971	7486	8758	9674
81	Ulsoor	22152	23944	26449	31757	34701	37917	17260	18656	20608
82	Hoysalanagar	30027	33181	35933	42692	46703	51090	17845	19720	21355
83	Sir C.V. Raman Nagar-South	27312	33181	35933	7230	8293	9513	3517	4273	4627
84	Benniganahalli	43838	51800	58651	12967	18831	27348	232	274	310
85	Sarvagna Nagar	30131	34533	39101	7973	9082	10346	17799	20400	23098
86	Maruthisevanagar	29551	36567	40393	5261	6151	7192	6401	7921	8750
87	Lingarajapuram	23267	24378	26929	19358	20825	22405	13422	14063	15535
88	Banaswadi	30822	35472	39966	12768	14539	16556	11669	13430	15131
89	Kacharakanahalli	20315	23648	26644	2381	4398	8123	2305	2683	3023
90	Sagayapura	56609	62781	65991	1586	3046	5849	1565	1736	1825
91	Pulakeshinagar	38117	41456	43576	12697	13575	14515	14328	15583	16380
92	Jayamahal	42664	47086	49494	2394	4028	6777	2888	3187	3350
93	Devarajeevanahalli	28357	32249	33898	2654	4363	7173	1868	2125	2234

Ward_ no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
94	Kadugondanahalli	19089	21499	22599	5899	6419	6984	6312	7110	7473
95	Kaval Byrasandra-West	30175	35607	38561	4574	5171	5845	1578	1862	2017
96	Hebbal-East	13083	15260	16526	19309	21702	24390	12544	14631	15845
97	Jayachamarajendranagar	41906	47435	50862	20659	22760	25074	21017	23790	25509
98	Ganganagar-HMT Layout	40425	44405	48088	4327	6626	10147	1790	1967	2130
99	Aramane nagar	39214	45009	48743	11816	13173	14687	6570	7541	8167
100	Sanjayanagar-East	32946	33205	33539	3561	4476	5625	3745	3774	3812
101	Mathikere-South	40569	43462	46142	1411	3276	7605	1875	2009	2133
102	Basaweshwaranagar	36532	41368	43483	4967	5419	5912	4902	5551	5835
103	Industrial Town-east	37036	42616	46151	7733	8632	9636	5474	6299	6821
104	MRCR Layout	44372	47020	49424	686	2154	6764	1171	1240	1304
105	Deepanjali Nagar	38204	41886	45360	8170	8902	9700	7243	7942	8600
106	MohamadanBlock/Jayanagar II block	28811	32960	36408	824	1583	3041	934	1068	1180
107	Banashankari I Stage	30457	32960	36408	4458	4874	5329	3044	3294	3639
108	Kathriguppe	34071	44531	49189	7551	9073	10902	8777	11472	12672
109	Bhuvaneshwarinagar	40477	41418	43537	5632	5841	6058	8992	9201	9672
110	Padmanabhanagar	40477	48892	52947	7574	8662	9907	9952	12021	13018
111	Kari Sandra	58821	63097	66324	1223	1299	1379	2732	2930	3080
112	JP Nagar II, III, IV, V phase	34418	45176	57491	1533	3404	7560	1016	1333	1696
113	Jayanagar VII, VIII	36287	40578	43944	3226	4720	6906	6714	7507	8130
114	Byrasandra, Tilak Nagar	48210	53131	56407	1578	2766	4847	1560	1719	1825
115	Hombegowdanagar	49035	51841	56141	12689	13577	14527	11589	12252	13268

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
116	Adugodi	43100	48441	50919	21258	23106	25114	10033	11276	11852
117	Gurappanapalya-West	56432	63606	68882	4009	4429	4894	2083	2348	2543
118	BTM Layout-South	68123	74789	80992	15300	16683	18190	6094	6690	7245
119	Madivala-West	48752	53056	57456	5204	6894	9133	6275	6829	7395
120	Koramangala-East	46201	53056	57456	2954	4761	7674	3892	4469	4840
121	Jakkasandra Layout	41573	47250	51987	3749	4193	4688	3040	3456	3802
122	Domlur-South	42047	47250	51987	1479	2936	5828	2187	2458	2705
123	Old Airport	43360	50572	55863	28100	31895	36203	5355	6246	6900
124	Sir C.V. Raman Nagar-North	27312	33116	36580	5877	6802	7872	3651	4427	4890
125	Kaval Byrasandra-East	28175	33116	36580	5164	5884	6704	1910	2245	2480
126	Hebbal-West	38083	41267	45404	4274	4667	5095	2422	2624	2887
127	Ganganagar-Gangenahalli	28425	33101	36419	8663	9806	11100	3121	3634	3999
128	Sanjayanagar-West	28246	33101	36419	1481	3199	6910	3828	4486	4936
129	Yelahanka (earlier CMC) - Ward No.1-14, 20, 21, 22, 29	58044	92682	143433	29165	35029	42071	21215	33875	52424
130	Yelahanka (earlier CMC) - Ward No.16-19	20404	32580	50421	1197	5242	22958	2447	3907	6046
131	Yelahanka (earlier CMC) - Ward No.15, 23-31	28832	46037	71247	2501	8091	26179	4228	6751	10448
132	Byatarayanapura(earlier CMC) - Ward No. 3 - 11	54074	89363	138297	7317	11702	18715	8324	13757	21290

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
133	Byatarayanapura(earlier CMC) - Ward No.12 - 16, 19	51570	85225	131893	4473	9793	21440	6691	11058	17114
134	Byatarayanapura (earlier CMC) - Ward No. 17, 18, 20-22, 27	40272	66554	102998	4869	10457	22454	5866	9694	15002
135	Byatarayanapura (earlier CMC) - Ward No. 23-26, 28-31	51732	85492	132308	12947	20706	33114	9763	16134	24969
136	K.R. Puram (earlier CMC) - Ward No. 1, 5-10	41977	69371	107359	10938	17493	27975	7340	12130	18772
137	K.R. Puram (earlier CMC) - Ward No. 2, 4, 12, 13, 14, 19	29823	49286	76274	36397	47918	63087	18801	31070	48084
138	K.R. Puram (earlier CMC) - Ward No.11, 29-33	46868	77454	119868	8679	13880	22198	8154	13475	20853
139	Mahadevapura (earlier CMC) - Ward No.1-11	51740	85506	132328	5126	10884	23110	8283	13688	21183
140	K.R. Puram (earlier CMC) - Ward No. 3, 15-18, 34, 35	40726	67304	104159	15980	25555	40869	11884	19640	30394
141	Mahadevapura (earlier CMC) - Ward No.12,13,21,22,24	32140	53115	82200	6623	13358	26939	6223	10284	15915
142	Mahadevapura (earlier CMC) - Ward No.14-20	33138	54764	84752	46127	73767	117971	8836	14602	22598
143	K.R. Puram (earlier CMC) - Ward No. 21, 22, 24, 26	36440	60221	93197	4058	9095	20380	3831	6331	9797

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
144	K.R. Puram (earlier CMC) - Ward No. 20, 23, 25, 27, 28	24108	39841	61658	4359	6970	11147	4148	6856	10610
145	Mahadevapura (earlier CMC) - Ward No. 23,25-31	43374	71680	110932	30534	54728	98093	9988	16507	25546
146	Bommanahalli (earlier CMC) - Ward No. 1-5	40022	66140	102024	17898	28577	45626	7602	12562	19378
147	Bommanahalli (earlier CMC) - Ward No. 12-16	36096	59652	92016	27056	43199	68972	7812	12911	19916
148	Bommanahalli (earlier CMC) - Ward No. 6-9	32021	52918	81628	52486	70165	93799	12316	20354	31397
149	Bommanahalli (earlier CMC) - Ward No. 10, 11, 17, 18	31535	52115	80389	4505	7193	11485	2842	4697	7246
150	Bommanahalli (earlier CMC) - Ward No. 23-27	32772	54159	83543	11456	14832	19204	5764	9526	14694
151	Bommanahalli (earlier CMC) - Ward No. 19-22	29176	48216	74376	7587	12113	19340	3669	6064	9354
152	Bommanahalli (earlier CMC) - Ward No 28-31	36559	60418	93196	6849	10935	17459	3733	6169	9516
153	Pattanagere (earlier CMC) - Ward No. 13-29	45551	72733	112194	7732	12135	19044	9333	14903	22988
154	Kengeri (earlier TMC) - Ward No. 1-23	50146	82871	127881	20792	33203	53022	18883	31206	48154

Ward_no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
155	Pattanagere (earlier CMC) - Ward No.1-12	41482	66236	102172	6625	10398	16319	6201	9901	15272
156	Dasarahalli (earlier CMC) - Ward No. 31-33	33607	53600	82680	11660	18289	28686	10583	16879	26037
157	Dasarahalli (earlier CMC) - Ward No. 24, 34, 35	51016	81366	125510	3518	5518	8655	3081	4913	7579
158	Dasarahalli (earlier CMC) - Ward No. 26, 29, 30	42071	67100	103504	1233	1933	3032	3478	5547	8556
159	Dasarahalli (earlier CMC) - Ward No. 23, 25, 27, 28	34627	55227	85190	5782	9070	14226	6418	10236	15790
160	Dasarahalli (earlier CMC) - Ward No. 17-22	38209	60940	94002	7669	12029	18867	7839	12502	19284
161	Dasarahalli (earlier CMC) - Ward No.4, 9-16	51632	82348	127026	18829	26153	36325	15594	24871	38364
162	Dasarahalli (earlier CMC) - Ward No.5-8	43343	69128	106633	5883	9228	14474	4576	7298	11257
163	Hunasemaranahalli	77326	123564	191227	7023	17250	42368	4512	7210	11157
164	Chikkagubbi	61411	98133	151870	2467	8760	31102	14289	22833	35337
165	Seegehalli	39677	63402	97894	9348	20064	43065	4324	6910	10669
166	Devarabeesanahalli	55522	88722	136909	8094	12710	19959	9207	14712	22703
167	Kodathi	30034	47993	74060	8033	12615	19809	5342	8537	13174
168	Huskuru	88538	141372	218155	22421	35194	55244	14290	22818	35211
169	Begur	57641	92038	142026	12439	19525	30649	7141	11402	17594
170	Thalaghattapura	115786	191348	295273	19670	31412	50163	8357	13810	21311

Ward_ no	Traffic_Zone	Population			Employment			School Enrollment		
		2005	2015	2025	2005	2015	2025	2005	2015	2025
171	Gollahalli	112078	178960	276157	8924	14009	21990	4788	7645	11797
172	Machohalli	42795	68333	105447	5293	8309	13043	6876	10980	16943
173	Makali	100429	160482	247644	17162	26949	42318	9650	15420	23795
174	Ivar Kandapura	53502	85495	131929	3738	5869	9217	2525	4034	6226
175	Bagaluru	750	1875	4688	90	225	703	150	375	938
176	Kodigahalli	3750	9375	23438	450	1125	3516	750	1875	4688
177	Nellukunte	30312	75781	180777	7012	17531	48679	6062	15156	36155
178	Hosuru	800	2000	25000	296	740	128750	160	400	5000
179	Devanahalli	62823	157057	350000	7539	18847	52500	12565	31411	70000
180	Minakunte	14359	35896	85631	2411	6026	17251	2872	7179	17126
181	Chikkajala	11168	27919	66602	2653	6632	18397	2234	5584	13320
182	Basavana Gudda	26324	65810	156990	5096	12741	35924	5265	13162	31398
183	Singahalli	400	1000	3000	8173	20433	122325	80	200	600
184	Mailanahalli	200	500	2000	274	685	101863	40	100	400
185	Bavuru	200	500	2000	1624	4060	10300	40	100	400
186	Arasinakunte	200	500	2000	424	1060	3300	40	100	400
187	Bettakote	400	1000	2000	448	1120	80300	80	200	400
188	Bavanahalli	17151	30615	62109	2744	5511	12422	3430	6123	12422
189	Sadahalli	5046	9006	18271	807	1621	3654	1009	1801	3654
190	Kodenahalli	17392	31045	62981	2783	5588	12596	3478	6209	12596
191	Budigere	18893	33724	68417	3023	6070	13683	3779	6745	13683

Source: CTTP report

Appendix –D: Mode table and transit network setting

Table 2: Mode table to differentiate mode travel times and acceptable access and egress times

Mode_Name	Mode_ID	Mode Used	Type	Max Access	Max Egress	Impedance Field
Bus	1	1		10	10	Transit travel time
Metro	2	1		20	20	Metro travel time
walk	3	1		0	0	walk travel time

Source: Author compilation

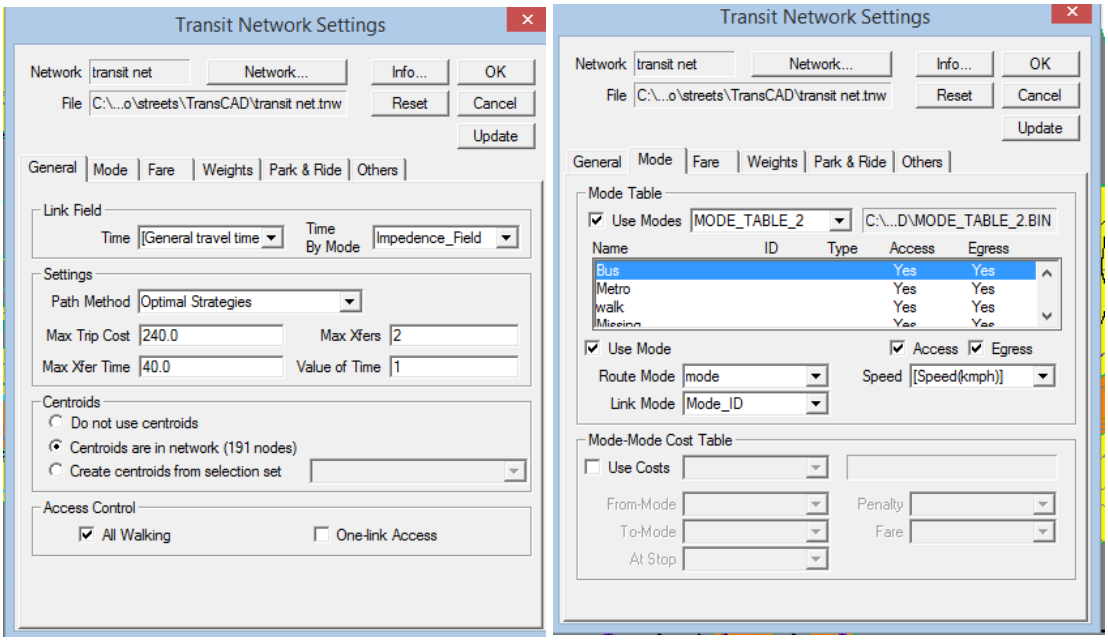

Figure 1: Network settings

Appendix –E: Network level analysis results

Table 3: Spatial and temporal availability of Transit

Parameter	Bengaluru city	within 10 min buffer of transit
Area	1718.75	29.62851
Population	9331761	78.65466

Source: Author compilation

Table 4: TAAI of existing and proposed transit system and savings in transit GC after metro

CTTP ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
1	96.114	82.909	37.894	51.177	1.931	1.489	1.166	0.748	13.739
2	68.403	58.817	28.964	39.172	1.793	1.388	1.134	0.733	14.014
3	72.878	52.144	31.119	41.953	1.723	0.881	1.355	0.520	28.450
4	67.405	67.367	30.657	41.645	1.393	1.397	0.686	0.632	0.056
5	63.429	63.270	26.319	35.923	1.600	1.591	0.830	0.818	0.251
6	61.624	42.863	24.573	33.376	1.677	0.862	0.979	0.367	30.444
7	71.163	70.984	27.106	36.856	1.905	1.872	1.290	1.110	0.252
8	62.389	62.258	24.611	33.214	1.758	1.805	1.046	1.014	0.210
9	67.012	45.129	23.442	31.670	2.145	1.097	1.350	0.554	32.656
10	64.742	46.992	28.625	38.760	1.489	0.753	0.827	0.290	27.417
11	74.608	56.003	34.677	47.799	1.481	0.756	0.823	0.279	24.938
12	70.130	59.371	28.293	38.599	1.725	1.266	1.016	0.657	15.342
13	67.280	56.856	27.354	36.678	1.673	1.186	1.091	0.715	15.494
14	63.209	43.348	23.598	32.220	1.935	1.010	1.216	0.476	31.421
15	63.131	43.828	24.971	33.889	1.692	0.864	1.095	0.414	30.576
16	62.631	52.844	25.897	34.342	1.597	1.157	1.048	0.692	15.627
17	64.161	63.981	28.390	38.389	1.455	1.447	0.811	0.807	0.281
18	62.961	62.565	27.110	36.584	1.462	1.468	0.809	0.791	0.629
19	63.888	52.958	25.063	33.374	1.685	1.225	0.973	0.639	17.109
20	58.310	47.865	22.018	29.867	1.839	1.352	1.022	0.658	17.913
21	59.515	49.651	23.897	32.507	1.637	1.206	0.825	0.537	16.574
22	57.175	47.858	23.184	31.281	1.603	1.185	0.873	0.570	16.296
23	63.240	44.333	25.654	34.412	1.631	0.817	0.960	0.362	29.897
24	75.554	49.985	24.876	33.539	2.343	1.201	1.190	0.499	33.842
25	60.022	41.431	23.683	32.019	1.633	0.847	0.967	0.360	30.975
26	54.633	37.572	21.442	28.985	1.697	0.867	0.991	0.376	31.228
27	60.472	42.178	24.538	33.555	1.527	0.814	0.860	0.306	30.252
28	55.940	38.723	22.282	30.292	1.646	0.871	0.883	0.327	30.777
29	57.309	38.928	21.530	29.104	1.780	0.906	1.001	0.389	32.073

CTTP ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
30	59.899	40.555	22.165	30.485	1.893	0.977	0.911	0.352	32.295
31	60.014	59.236	23.515	31.708	1.667	1.723	0.884	0.884	1.297
32	62.729	42.702	23.511	31.783	1.870	0.925	1.117	0.441	31.927
33	61.303	42.784	24.916	33.923	1.625	0.822	0.994	0.373	30.209
34	68.149	47.152	26.757	36.309	1.730	0.904	0.981	0.381	30.810
35	66.087	46.617	27.616	37.675	1.540	0.766	0.959	0.348	29.461
36	64.446	54.395	26.944	36.663	1.525	1.135	1.013	0.665	15.595
37	81.072	80.997	32.655	43.865	1.686	1.675	1.169	1.154	0.092
38	91.354	90.925	32.043	45.058	2.121	2.131	1.369	1.256	0.470
39	74.043	52.212	30.831	43.547	1.571	0.768	0.871	0.293	29.484
40	72.584	50.556	28.976	40.354	1.674	0.832	0.832	0.300	30.349
41	69.173	57.478	27.310	37.522	1.727	1.231	0.841	0.542	16.906
42	63.498	43.577	24.350	33.700	1.862	0.919	0.722	0.274	31.372
43	63.109	51.438	23.388	31.962	1.929	1.372	1.274	0.816	18.494
44	60.100	48.802	22.254	30.313	1.893	1.347	1.045	0.671	18.798
45	64.350	63.532	22.996	31.513	2.113	2.139	1.265	1.249	1.271
46	59.228	48.579	22.707	30.865	1.902	1.303	0.734	0.470	17.981
47	56.701	39.115	22.404	30.758	1.656	0.861	0.968	0.351	31.015
48	60.952	50.633	24.133	32.930	1.659	1.213	1.091	0.704	16.929
49	59.152	40.377	22.374	30.312	1.928	0.992	1.185	0.469	31.740
50	59.208	40.801	23.208	31.609	1.745	0.862	1.058	0.400	31.090
51	72.903	60.094	27.738	37.436	2.228	1.420	1.665	1.058	17.571
52	90.839	90.214	25.351	33.990	3.002	3.226	1.995	1.975	0.688
53	82.991	82.180	25.895	35.222	2.384	2.549	1.738	1.729	0.978
54	75.303	74.680	28.578	38.901	1.805	1.842	1.194	1.176	0.827
55	75.548	75.117	29.045	40.105	1.780	1.812	0.839	0.824	0.571
56	66.458	56.649	28.604	39.375	1.726	1.136	0.484	0.313	14.759
57	74.826	52.042	29.856	41.155	1.742	0.847	1.104	0.410	30.450
58	68.975	49.205	30.153	40.431	1.527	0.722	1.007	0.374	28.663
59	64.955	45.241	26.040	35.288	1.742	0.855	0.998	0.379	30.351
60	63.684	44.636	26.284	35.287	1.637	0.810	0.958	0.365	29.910

CTTP ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
61	64.186	44.519	25.658	34.843	1.633	0.815	1.041	0.389	30.641
62	68.110	56.966	27.541	37.042	1.606	1.169	1.035	0.679	16.361
63	76.375	52.660	29.275	39.301	1.854	0.925	1.206	0.481	31.051
64	59.916	42.567	25.852	35.364	1.475	0.735	0.843	0.296	28.956
65	72.332	51.051	30.256	41.646	1.614	0.780	0.944	0.338	29.422
66	65.826	57.487	30.590	42.450	1.339	0.959	0.827	0.543	12.668
67	75.166	62.714	30.142	40.909	1.717	1.192	1.025	0.665	16.566
68	69.385	68.548	29.276	39.546	1.619	1.664	0.933	0.917	1.207
69	73.589	50.842	29.092	39.131	1.593	0.809	0.922	0.346	30.910
70	67.791	46.018	25.418	34.573	1.751	0.857	0.684	0.256	32.118
71	73.300	61.147	29.574	40.442	1.530	1.150	0.691	0.450	16.581
72	72.812	60.337	28.884	39.787	1.751	1.311	1.077	0.688	17.132
73	71.274	69.705	30.710	42.150	1.380	1.406	0.635	0.619	2.201
74	95.383	94.281	34.077	45.997	2.053	2.233	0.953	0.938	1.156
75	76.865	64.101	30.636	41.848	1.631	1.202	0.958	0.620	16.606
76	66.067	46.270	27.066	37.142	1.526	0.779	0.674	0.235	29.965
77	58.085	40.397	23.478	32.229	1.528	0.818	0.647	0.225	30.453
78	64.942	54.359	26.331	35.616	1.525	1.169	0.670	0.437	16.296
79	63.937	44.785	26.537	36.173	1.506	0.792	0.641	0.229	29.954
80	66.418	45.541	25.974	35.017	1.675	0.859	1.083	0.415	31.432
81	72.019	49.732	28.237	38.390	1.656	0.887	0.658	0.250	30.945
82	74.256	51.960	30.697	42.250	1.581	0.799	0.776	0.280	30.026
85	82.603	68.779	32.747	44.438	1.728	1.224	0.937	0.606	16.736
86	90.493	89.684	33.425	44.783	1.996	1.978	1.228	1.139	0.894
87	92.008	91.272	36.201	48.867	1.751	1.740	0.855	0.827	0.801
88	82.764	82.496	39.248	54.283	1.208	1.210	0.587	0.576	0.323
89	79.788	67.455	33.572	45.976	1.591	1.162	0.811	0.528	15.457
90	73.208	51.075	29.827	40.441	1.663	0.842	1.235	0.473	30.233
91	71.168	49.220	28.307	38.400	1.650	0.826	0.972	0.364	30.839
92	73.635	62.585	31.012	41.928	1.589	1.148	0.985	0.641	15.006
93	79.463	54.998	31.364	42.035	2.102	1.033	1.281	0.529	30.788

CTT P ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
94	76.659	54.796	33.973	45.821	1.494	0.731	0.712	0.261	28.519
95	86.667	72.991	36.217	48.100	1.639	1.169	1.047	0.690	15.780
96	99.486	98.854	37.275	50.553	2.040	1.900	0.683	0.683	0.635
97	78.006	77.529	33.340	44.769	1.709	1.572	1.218	1.205	0.612
98	73.325	72.638	31.065	42.141	1.615	1.678	1.081	1.076	0.937
99	68.477	68.327	28.661	38.902	1.527	1.576	0.894	0.879	0.219
100	81.021	79.586	36.883	51.047	1.453	1.434	0.779	0.764	1.771
101	60.123	42.990	25.926	35.297	1.547	0.776	0.868	0.312	28.496
102	67.162	67.148	28.758	38.636	1.541	1.534	0.917	0.903	0.021
103	57.620	39.708	22.565	30.571	1.668	0.856	1.003	0.380	31.088
104	57.716	40.125	23.221	31.894	1.654	0.841	1.016	0.377	30.479
105	67.344	47.278	27.584	39.430	1.782	0.831	0.931	0.319	29.797
106	63.005	43.772	25.115	33.935	1.712	0.857	0.969	0.370	30.526
107	82.227	81.346	24.888	33.690	2.810	2.978	1.739	1.727	1.071
108	74.155	73.664	29.449	40.009	1.687	1.751	1.072	1.065	0.662
109	76.116	75.775	30.974	43.382	1.572	1.566	0.851	0.851	0.447
110	72.486	61.189	29.935	41.550	1.734	1.232	1.043	0.667	15.585
111	60.998	43.171	25.998	35.316	1.586	0.813	1.105	0.414	29.225
112	68.266	47.463	27.315	37.689	1.736	0.860	1.001	0.371	30.474
113	59.530	42.274	25.695	34.609	1.572	0.796	0.938	0.354	28.986
114	70.315	57.313	25.956	34.624	1.990	1.390	1.360	0.876	18.491
115	61.883	43.267	25.377	34.807	1.562	0.784	0.956	0.342	30.082
116	65.098	45.211	26.204	35.604	1.605	0.818	0.964	0.357	30.549
117	56.160	40.172	24.716	33.564	1.486	0.744	0.955	0.342	28.469
118	82.925	58.324	34.217	46.889	1.617	0.825	1.225	0.453	29.667
119	67.989	47.563	27.575	37.937	1.615	0.849	0.998	0.365	30.043
120	68.587	67.879	29.476	40.586	1.501	1.537	0.908	0.908	1.033
121	78.601	77.936	32.790	44.709	1.552	1.534	0.876	0.876	0.845
122	89.762	89.404	35.377	47.350	1.756	1.782	1.148	1.137	0.399
123	89.957	89.353	39.110	53.498	1.476	1.490	0.915	0.915	0.672
124	81.026	58.360	35.968	50.259	1.392	0.686	0.602	0.183	27.974

CTTP ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
125	78.145	55.386	34.079	45.504	1.586	0.782	1.005	0.390	29.125
126	69.423	69.055	31.834	44.438	1.354	1.360	0.762	0.758	0.530
127	68.038	67.711	29.772	40.824	1.416	1.420	0.707	0.707	0.481
128	81.486	79.125	33.789	46.482	1.686	1.691	0.915	0.911	2.897
129	106.510	103.456	58.503	82.653	1.177	1.080	0.899	0.876	2.867
130	117.379	115.236	59.806	84.147	1.149	1.157	0.482	0.475	1.826
131	79.090	77.456	41.638	58.782	1.326	1.244	0.630	0.617	2.066
132	98.896	94.789	43.692	59.986	1.489	1.555	1.077	1.063	4.153
134	87.641	84.398	42.140	58.941	1.217	1.227	0.762	0.758	3.701
135	79.438	59.819	40.141	55.635	1.128	0.563	0.936	0.264	24.697
136	93.864	93.609	42.482	58.670	1.420	1.396	0.831	0.827	0.272
137	89.567	89.219	44.203	62.357	1.372	1.223	0.601	0.597	0.389
138	78.005	56.949	36.115	50.193	1.369	0.687	0.918	0.292	26.993
139	72.099	63.117	33.647	47.541	1.425	1.039	0.829	0.531	12.458
140	83.195	60.367	37.564	53.158	1.494	0.726	0.889	0.279	27.440
141	103.710	103.413	40.794	56.469	1.767	1.792	0.981	0.957	0.286
142	93.667	70.074	46.611	65.526	1.131	0.583	0.618	0.148	25.189
144	86.177	85.652	36.239	49.606	1.713	1.810	0.920	0.920	0.610
145	98.501	95.634	45.777	63.345	1.387	1.400	1.120	1.108	2.911
147	69.761	50.343	31.345	43.970	1.343	0.659	0.721	0.211	27.836
148	95.498	72.112	48.449	68.001	1.047	0.514	0.368	0.068	24.488
150	82.916	58.551	34.773	47.704	1.766	0.866	1.180	0.450	29.385
151	102.203	89.859	47.591	65.478	1.277	0.955	0.621	0.411	12.078
152	94.541	75.861	32.497	45.154	2.381	1.540	1.617	1.017	19.758
153	113.356	95.364	44.999	62.404	1.577	1.212	1.215	0.777	15.872
154	106.211	79.939	52.949	75.437	1.137	0.557	0.633	0.136	24.735
155	92.305	91.198	38.753	54.030	1.535	1.537	1.058	1.058	1.199
156	77.817	75.690	35.226	48.312	1.685	1.468	0.988	0.967	2.733
157	83.025	81.762	40.246	54.790	1.481	1.501	1.060	1.054	1.522
158	71.690	69.846	31.373	42.973	1.599	1.604	1.049	1.043	2.573
159	76.337	73.632	38.642	51.891	1.326	1.296	0.780	0.767	3.543
160	77.901	61.760	38.517	53.181	1.553	0.798	0.911	0.310	20.720

CTTP ID	Average GC_Bus	Average GC_PT+Metro	Average GC_ Motor Bike	Average GC_Car	TAAI_Bus_ Motorbike	TAAI_Bus+Metro_Motorbike	TAAI_Bus_Car	TAAI_Bus+Metro_Car	GC savings in percentage
161	74.285	61.921	39.696	54.649	1.419	0.738	0.940	0.293	16.644
162	75.393	70.342	50.873	69.253	1.677	1.409	0.958	0.644	6.699
165	108.481	108.317	54.788	77.953	1.046	1.089	0.436	0.436	0.152
166	104.329	102.756	52.893	74.251	1.051	1.088	0.511	0.507	1.508
173	120.896	120.315	60.767	81.034	1.021	1.060	1.037	1.026	0.481
176	130.497	127.798	87.252	121.007	0.572	0.556	0.097	0.091	2.068
189	177.337	174.876	100.143	146.247	0.878	0.877	0.184	0.169	1.388

Source: Author compilation