A COMPARATIVE EMPIRICAL ANALYSIS OF THE RELATIONSHIP BETWEEN PUBLIC TRANSPORT AND LAND USE CHARACTERISTICS

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ABSTRACT

A combination of apartheid policies and market forces have resulted in expansive and inefficient urban forms in South African cities. Current spatial development plans attempt to curb this expansion and manipulate land use characteristics to achieve socially beneficial goals. An increasingly important goal, recognised in contemporary South African urban policy and legislation, is the improvement of public transport quality, efficiency and viability. The links between urban form and public transport networks are, however, not well understood, and little empirical research of this relationship has been undertaken. A review of the available literature suggests that the land use characteristics of urban density, land use mix and polycentrism have the most significant effect on public transport efficiency and viability. A review of the South African transport policy environment reveals five land use-related public transport objectives (relating to coverage, quality-of-service, modal split, subsidisation and household expenditure). Increased urban density is argued to be a pre-condition for attaining all of these policy objectives. South African city-wide densification targets (typically around 80 persons/ha) are compared to the densities of international cities that have achieved the policy objectives identified in South African policy. This comparison suggests that South African densification targets may be lower than required, and that targets in the region of 140-190 persons/ha might be more appropriate. Poor availability of data on urban form-public transport relationships is identified as a problem, and it is argued that simulation research is needed to gain greater insight, particularly in relation to the impacts of articulated density, land use mix and polycentrism.

1   INTRODUCTION

It has been widely acknowledged in recent policies and strategies that the intensity and distribution of land uses in South African cities is not conducive to efficient public transport systems, and represents a substantial obstacle to their reform (Grey & Behrens, 2013; Turok, 2011). With aspirations to create better quality, more viable, and more equitable public transport networks, these cities need to proactively adapt their land use environments (DoT, 2007b). This paper explores the effects of land use characteristics on the efficiency and viability of public transport systems. Using empirically observed correlations in secondary datasets, it tests the ability of South African policy targets, with respect to necessary land use changes, to achieve transport policy objectives.

The paper is divided into five sections. The following section reviews existing literature in order to identify: a prominent set of theoretical propositions with respect to the effect of different land use characteristics on public transport; and contemporary land use-related South African public transport policy objectives.

Section 3 tests the strength of the identified propositions through an analysis of available international city transport data, and uses the correlations found to reflect critically upon the assumptions embedded in contemporary South African policy objectives.

Section 4 identifies gaps in the empirical research undertaken in this field, and section 5 discusses how an ongoing dissertation may aid in filling some of these gaps in the South African context.

2 LITERATURE REVIEW

Almost every land use characteristic has some indirect impact on public transport quality, viability or efficiency. This section will begin with a brief review of literature relating to the primary interactions between public transport networks and land use characteristics. Based on this literature, the principal land use characteristics will be proposed, and a conceptual basis for each one's relationship with public transport will be developed. The review will then extend to the South African transport policy environment and the land use-related public transport objectives contained therein. As the bulk of the literature and secondary data in the field relates to the impact of density, the review will conclude with a summary of densification targets that have been set by some South African cities.

2.1 Public transport related land use characteristics

On the basis of a review of existing literature, it is proposed that three land use characteristics – urban density, land use mix and polycentrism – have the strongest relationship with public transport quality, viability and efficiency.

2.1.1 Urban density

Urban density affects the volume of passengers, or ridership, that utilises a public transport service (Newman, 1989). Threshold ridership is the volume of passengers that a public transport service requires to be financially viable (Wang, 2008). Ridership is largely dependent upon access to the system, which is derived from the generalised cost and the user's proximity to a public transport station or stop (Wang, 2008).

It is claimed that every public transport user is also a pedestrian, which is why the maximum proximity of a user is often assumed to be the maximum distance a user is willing to walk to the point of access (Mees, 2010b; Murray et al., 1998). The maximum proximity delineates the extent of the effectual catchment area from which passengers will likely utilise the public transport stop. Therefore, most of the passengers that are required to meet the threshold ridership of the service will live or work within the collective catchment area of its stops, and those of its feeder services. Consequently, the number of users that are likely to utilise the service, from within the catchment area, is fundamentally dependent on urban density (Wang, 2008). The threshold ridership will then have an accompanying threshold urban density that is based on the modal split of the area.

If user costs are kept relatively constant, the threshold ridership is based on the financial cost of operating the service (Murray et al., 1998). A high threshold ridership is representative of a public transport system that is modern, efficient and of high quality (Murray et al., 1998). To maximise quality-of-service but remain financially viable, a public transport service needs to have a threshold ridership that is equal to the number of passengers that are likely to utilise it (Wang, 2008). This means that an expensive, high capacity subway system, with a very high threshold ridership, will require an equally high urban density to remain viable.

There are numerous methods and units for measuring urban density. 'Gross population density', the persons per hectare for an entire city, and 'net population density', the persons per hectare for residential land only, are among the most common

(Suzuki et al, 2013). Gross and net residential densities are calculated in a similar manner: using residential dwellings per hectare (Suzuki et al, 2013). 'Articulated density' refers to how strategically the population density is distributed over the metropolitan area with regard to public transport proximity or transit oriented development (Suzuki et al, 2013). 'Activity intensity' combines population density with job density as both ends of a commute need to attain a high level of density in order to have a significant effect on travel behaviour and public transport viability (Newman, 2006; Cervero, 1991).

2.1.2 Land use mix
Land use mix affects trip length and the degree of seat renewal or 'renovation' that is achieved by a public transport vehicle during a completed trip (Suzuki et al, 2013). In the past, Euclidean zoning practices segregated residential areas from the pollution generated by industrial facilities and major retail environments (Cervero, 1991). Despite the advent of modern, non-polluting industries and retail developments, the segregation of land uses persists in many cities as an anachronism (Newman, 2006). The greater the mix of land use types, the closer an average resident is to the nearest place of retail and other amenities (Newman, 2006). This leads to a higher percentage of short public transport trips (Suzuki et al, 2013).

This is important for public transport systems as shorter trips are generally more expensive per kilometre for the passenger, but passengers make a greater number of trips as the cost of each trip is low (Newman, 2006). Shorter trips also mean that more passengers can use the same seat on a vehicle through the duration of the route, increasing vehicle productivity: this is the concept of seat renovation. Vehicles satisfying more trips at a higher per kilometre fare, substantially increases the revenue of a public transport service (Newman, 2006). Furthermore, the differing periods of peak demand for different land uses mean that the passenger volumes on an adjacent public transport route will be more evenly spread throughout the day and week, and 'peak-to-base' ratios will be reduced (Suzuki et al, 2013).

The indicators for land use mix come in the form of land use indices, such as 'entropy', 'dissimilarity', 'variability' and 'concentration', among others (Bordoloi et al., 2013). The indices require detailed land use information on a local scale and are not easily comparable (Manaugh & Kreider, 2013). Land use 'entropy' is currently the most commonly used index and quantifies the homogeneity of land use within a given area or census tract (Bordoloi et al., 2013). Equation 1 utilises the proportional area of the different land uses to determine an index score, but does not account for their distribution pattern nor the likelihood of significant interaction between them (Manaugh & Kreider, 2013).

$$Entropy = \sum_{j} P_j \times \frac{\ln(P_j)}{\ln(J)}$$

Equation 1:   *Entropy Index Equation, Pj = the proportion of total developed area of jth land-use category found in the study area, J = total number of land uses under consideration (Kockelman, 1997).*

2.1.3 Polycentrism

The degree of polycentrism affects trip length and directional flows (Suzuki et al, 2013). It is closely linked to land use mix, but focusses at a larger scale, primarily on passengers' home-based work trips.

In a monocentric city, the vast majority of work commutes are from the residential areas to a central business district (CBD), where most employment opportunities are located (Newman, 1989). The volume of passengers increases rapidly as the public transport routes pass through residential areas toward the CBD (Newman, 1989). The cumulative nature of the demand pattern creates a considerable peak on the routes as they near the CBD (Bertaud, 2004). In low density cities, this pattern is advantageous as the economies of scale on the main radial routes allow larger vehicles and higher order public transport modes to operate more viably (Bertaud, 2004). This spatial pattern also creates a single area of high density in the centre of the city that can operate local routes more profitably (Bertaud, 2004). A well planned, monocentric city structure has allowed many of the smaller European cities, with populations of less than 2 million, to reduce subsidies with moderate urban densities (Naess, 1995). However, when low-income residents are situated on the urban periphery, as they are in most South African cities, the spatial structure forces the poor to travel great distances to their place of work, often taking up one seat for the entire length of the public transport corridor (Maunganidze & Del Mistro, 2012). This decreases the level of achievable seat renovation, and (in the case of distance-based fare systems) forces the urban poor to pay the highest fares for their daily work commute (Maunganidze & Del Mistro, 2012).

Furthermore, in larger and denser cities, immense infrastructure is required to enable transport services to meet the temporal spike in demand, which is then underutilised until the pattern is reversed for the homeward trip (Newman, 1989). In the morning peak period, the public transport vehicles are only servicing demand when travelling toward the CBD and are then underutilised on the return journey (Newman, 1989). The extraneous infrastructure investments and unbalanced route demand profiles considerably diminish the financial sustainability of public transport services under these conditions. As a city becomes more polycentric, the commuter trips will increasingly diversify their destinations (Cervero, 1991). The demand along the public transport routes will no longer be as cumulative and the tidal directional flow travel pattern will balance, increasing seat occupancy and vehicle productivity (Cervero, 1991).

An indicator of polycentrism is the jobs-housing ratio of each area, which can be calculated by comparing the job density profile of a city with its residential density profile (Cervero, 1991). Other measures of polycentricity analyse the employment density distribution in more detail, including the Local Indices of Spatial Autocorrelation (LISAs) and Special Functional Polycentricity (Psf) measure (Riguelle 2007, Veneri 2010).

2.2 South African policy environment

Post-1994 South Africa produced transport policies that advocate affordable, equitable, efficient, viable and sustainable public transport. The first of these policies, the *White Paper on National Transport Policy*, stipulated that the provision of transport services should support economic and social development strategies whilst remaining economically sustainable (DoT, 1996). It stated that public transport should be promoted over car use and travel time and distance must be limited to 40 km or one hour in each direction (DoT, 1996). The *Moving South Africa* policy document called for public transport to first meet the needs of the marginalised users, in the form of captive passengers, scholars, tourists and users with disabilities (Republic of South Africa, 1998). It prescribed the use of measures to restrain car use and, over time, diversify public transport service types to cater to choice users (Republic of South Africa, 1998). Additionally, a goal was set to ensure that fares are affordable, but that the public transport systems still generate enough revenue to cover all operation and maintenance costs (Republic of South Africa, 1998).

The *National Land Transport Transition Act*, No. 22 of 2000, formalised, in legal terms, the visions of the two policy papers and reiterated the higher priority that was to be given to public transport over private modes of transport (Republic of South Africa, 2000).

More recently, The *Public Transport Strategy* (DoT, 2007) outlined how new Integrated Rapid Public Transport Networks (IRPTNs) would be able to accomplish the objectives set out by the earlier policy documents. IRPTNs are 'high quality networks of car-competitive public transport services that are fully integrated, have dedicated right-of-way and are managed and regulated by a capable municipal transport department' (DoT, 2007a). The networks are to be managed by companies linked to the metropolitan transport authorities and the strategy calls for a more active role for the public sector in transport supply and control (DoT, 2007). The strategy seeks to establish modern, efficient, high quality public transport systems for both captive and choice users that will be affordable, financially sustainable and accessible to most urban inhabitants (DoT, 2007b).

All four of these policy documents identify land use change as an important tool to achieve the objectives they set for public transport reform. The *White Paper on National Transport Policy* and *Moving South Africa* were insistent on the need to address low-density developments, spatially dislocated settlements and urban sprawl, in order to overcome the public transport challenges that the country faces (Republic of South Africa, 1998; DoT, 1996). The idea of intensive densification along 'development corridors' was given emphasis to ensure more efficient public transport travel patterns (Republic of South Africa, 1998; DoT, 1996). The *National Land Transport Transition Act* promoted densification through infilling as an addition to the high density corridors and proposed that land use planning be guided by transport planning (Republic of South Africa, 2000). The *Public Transport Strategy* suggested the proactive channelling and regulation of land use to secure the viability and sustainability of the IRPTNs (DoT, 2007b).[1]

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[1] The importance of the relationship between public transport and land use was succinctly articulated in the *White Paper on Western Cape Provincial Transport Policy*: *"To produce a transport system which is truly efficient, viable and affordable, and is sustainable into the future, it will be necessary to adopt policies on containment, densification and mixed land use, leading to a fundamental restructuring of the land use system in order to reduce the demand for movement. In addition, appropriate legislation will be established at the national and provincial levels to ensure that transport and spatial development are integrated and that land use development proposals are subject to an approved land use/transport policy framework."* (Western Cape Department of Transport and Public Works, 1997).

The ability of land use change to accomplish public transport objectives is rooted in the connections that the objectives have to the elements of urban form. The links that policy objectives have with land use characteristics are explored below in the form of a set of propositions.

2.2.1 Coverage
The *Public Transport Strategy* aims to have placed 85% of a South African metropolitan city's population within 1km of an IRPTN trunk or feeder service (DoT, 2007b). The distance of 1km was set by the *White Paper on National Transport Policy* as the desirable maximum walking distance to a public transport service in a metropolitan area (DoT, 1996). This distance delineates the catchment area that was referred to in relation to urban density. The urban density of the cities, and therefore their geographic footprint, will determine how many routes are required to meet this objective.

2.2.2 Quality-of-service
Two further objectives of the *Public Transport Strategy* are that trunk corridors operate with 5-10 minute headways during the peak period and for a minimum period of 16 hours (DoT, 2007b). Achieving these objectives for quality-of-service will also be dependent on urban density as they will increase the operational cost of services and therefore, their threshold ridership. Additionally, the more constant temporal demand distribution associated with areas of mixed land use will increase utilisation of the extended operating hours. Moreover, the bidirectional flow of commuters in a polycentric city will improve vehicle productivity during the high frequency, peak periods.

2.2.3 Modal split
One of the goals set by the *White Paper on National Transport Policy* is achieving a public transport motorised mode share of 80% for all weekday trip purposes (DoT, 1996). This goal would require high quality, efficient, car-competitive public transport systems. The associated high threshold ridership would need supportive urban density and land use mix to remain viable and retain affordable fares.

2.2.4 Subsidy
The minimisation or elimination of public-sector subsidies toward public transport system operations is stated as an aim of the IRPTNs in the *Public Transport Strategy* (DoT, 2007b). The concentration of passengers within catchments areas resulting from high urban density, the seat renovation rate from mixed land uses and the bidirectional flow pattern from a polycentric city will all be significant factors in achieving a level of revenue that covers all the operational costs of a public transport service.

2.2.5 Monthly transport expenditure
The *White Paper on National Transport Policy* has stipulated that commuters should spend less than 10% of their disposable income on transport (DoT, 1996). The utilisation of distance-based fare systems means that trip length is a significant determinant in transport expenditure. All three land use characteristics can reduce trip distance by placing trip origins closer to trip destinations.

2.3 Public transport related urban density targets

Various authors have posited threshold targets for land use characteristics that assure the viability and efficiency of different public transport modes. These targets are most often estimated as required minimum population densities, based upon assumptions relating to operating conditions and passenger travel behaviour. The South African metropolitan city governments have acknowledged the importance of urban density in creating more sustainable urban environments. The densification targets set by five South African cities[2] are summarised in Table 1.

Table 1:   *Various gross population density targets of selected South African cities (after Jones, 2014)*

TARGETED AREAS	SOUTH AFRICAN CITY / MUNICIPALITY				
	Cape Town (CoCT, 2012)	Tshwane (CoT, 2012)	Joburg (CoJ, 2010)	Nelson Mandela Bay (NMBM, 2007)	eThekwini (eThekwini Municipality, 2013)
ENTIRE URBANISED CITY AREA (persons/ha)	83	-	29[3]	78	79
ACTIVITY SPINES (persons/ha)[4]	393	150	-	340	209
DEVELOPMENT / PUBLIC TRANSPORT TRUNK CORRIDORS (persons/ha)	208	150	232	238	209

3   EMPIRICAL ANALYSIS

In order to better understand the relationships between land use characteristics and travel behaviour, Jeffrey Kenworthy and Felix Laube compiled the Millennium Cities Database (MCD) (Kenworthy, 2011). It has a reference year of 1995 but remains the most comprehensive database of city-specific transport indicators to date. It has been supplemented with data compiled by Paul Mees and the online Transit Oriented Development database, which have reference years of 2006 and 2010 respectively (CTOD, 2011; Mees, 2010a).The transport data on South African cities was collated by Danette Jones in 2013 (Jones, 2014), and supplemented by density data from Turok (2011). The collated database enables empirical testing of some of the propositions presented earlier.

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[2]   For comparison, the gross population density of the MyCiTi Phase 1A West Coast trunk corridor catchment area is approximately 44 persons/ha (Grey & Behrens, 2013).

[3]   This figure is based on the densification target of 10 units/ha stated in the City of Johannesburg: Spatial Development Framework (CoJ, 2003). It is noted that the current urban density of Johannesburg is higher than this target, which brings into question the accuracy of the value.

[4]   Activity spines are defined as significant metropolitan-wide activity routes directly linked to development, containing major economic nodes and business developments (CoCT, 2012).

The proposed connections between the three land use characteristics and the five related public transport policy objectives are summarised in Figure 1. Due to data unavailability, only the relationships between three of the policy objectives, and one of the land use characteristics, could be tested (highlighted in blue). The available data do not enable empirical analysis of relationships between policy objectives and land use mix or polycentrism. The data do enable a comparison of South African densification targets with the urban densities of international cities that have achieved the objectives identified in South African policy. They do not, however, enable empirical analysis of relationships between public transport coverage and quality-of-service policy objectives and urban density.
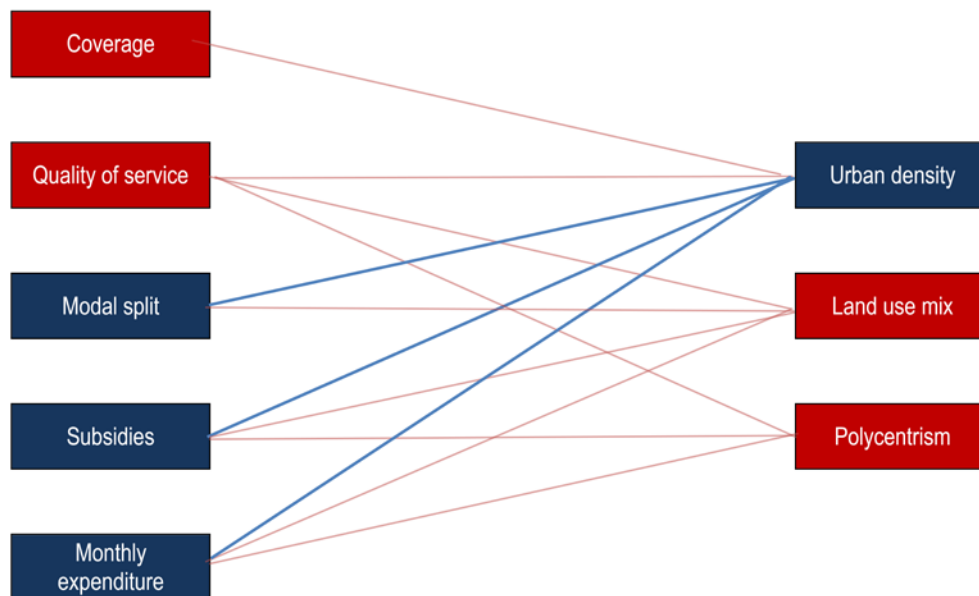

Figure 1:   *Diagram illustrating the connections between three land use characteristics and related public transport policy objectives*

Figure 2 presents the relationship observed between urban density and modal split. A clear and strong relationship exists in developed cities, represented by an R^2 value of 0.77, showing how urban density favours public transport modes and their mode share increases consistently in a logarithmic form. However, the relationship is not as clear in the smaller sample of developing cities, achieving an R^2 value of only 0.21.[5] Many low income residents in these cities, like those in South Africa, are captive to the public transport market, removing the option of choosing private transport even at very low urban densities. Similarly, the low quality of some public transport modes deters choice passengers at high urban densities.

The observed relationships suggest that the motorised mode share policy objective of 80% for public transport is high, with only Mumbai having attained it at an urban density of 337 persons/ha. Therefore, a more attainable goal of 60% public transport mode share has also been tested (Masemola *et al.*, 2013). The trend for all cities predicts that the average city would achieve this goal at an approximate urban density of 250 persons/ha, and for just developing world cities 190 persons/ha. One of the South African cities, Cape Town, has already achieved a mode share of 60%, as it has a large base of captive users and an extensive trunk rail network (Maunganidze & Del Mistro, 2012).

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5   The threshold between a developed and a developing world city was assumed to be a GDP/capita of $10,000 in 1995.

However, of the developed cities, only Hong Kong has a public transport mode share of more than 60%, at a density of 320 persons/ha. This suggests that as more residents become choice users, higher densities are needed to maintain the same public transport mode share. The range of gross population density targets set by the five South African cities, as illustrated on Figure 2, is considerably lower than even the urban density expected for a developing world city with a 60% public transport mode share.
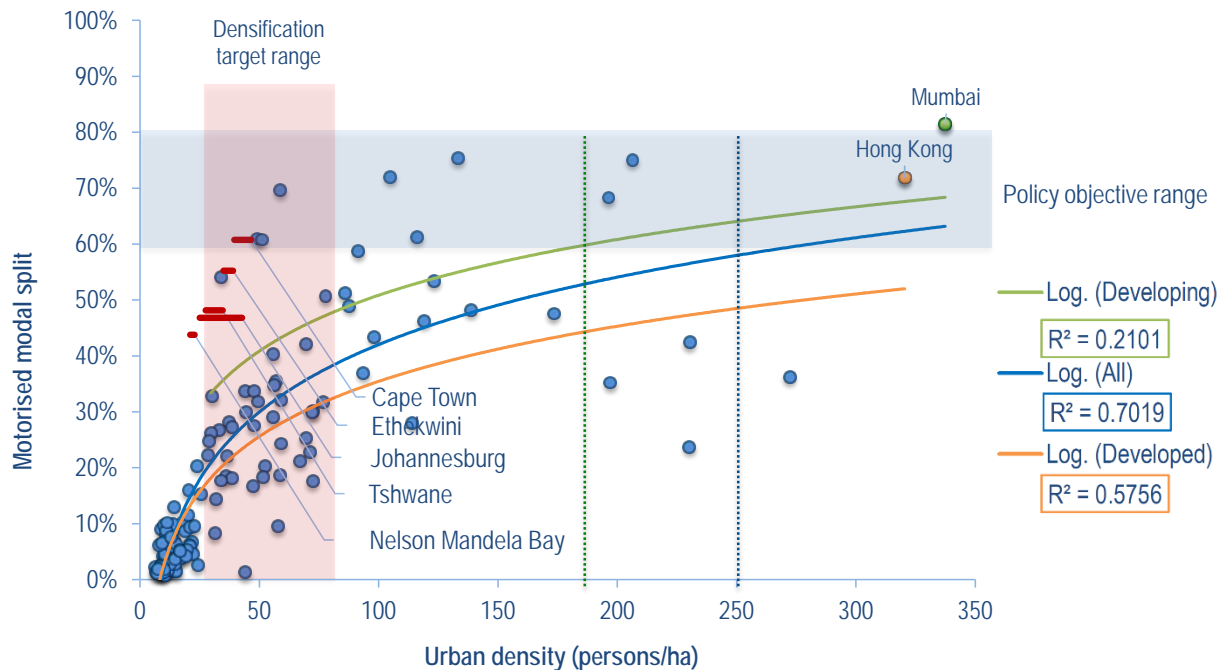

Figure 2:   *Public transport motorised modal split and urban density relationship, for all weekday trip purposes, for various cities (n=24 developing world cities, n=104 developed world cities)*

Figure 3 describes the relationship observed between urban density and the percentage of operating costs that is subsidized. The subsidy requirements of small public transport systems are susceptible to non-land use related factors (e.g. fare policies, minimum allowable levels of operation, overcrowding), therefore only the cities with a public transport mode share of more than 15% have been taken into account. An R^2 of 0.21 describes a relationship that is not as strong as in the case of mode share, but subsidisation levels do decrease with increasing urban density.

The South African policy objective for public sector subsidisation was its minimisation or elimination. Eleven cities in the dataset have no operating cost subsidisation. Of these, only Curitiba has an urban density that is lower than the targets set by the South African cities. Curitiba achieves this objective with low city-wide density by utilising the distribution of its density strategically, developing a density of 294 persons/ha along its public transport trunk corridors. It has followed a 1965 plan that led to it becoming arguably the best known case of articulated density and transit oriented development (Rabinovitch, 1996). The bidirectional flow of passengers along the high density corridors generates a seat occupancy of 78% throughout the day. Curitiba demonstrates the possibility that a low city-wide density can be an unfair representation of the urban density within the catchment areas of its public transport services. The data suggests that at approximately 140 persons/hectare operating cost subsidy in the average city reduces to 20%.

Therefore it is likely that South African cities would require a city-wide population density above this to eliminate subsidies, if articulated density and transit oriented development are not utilised.
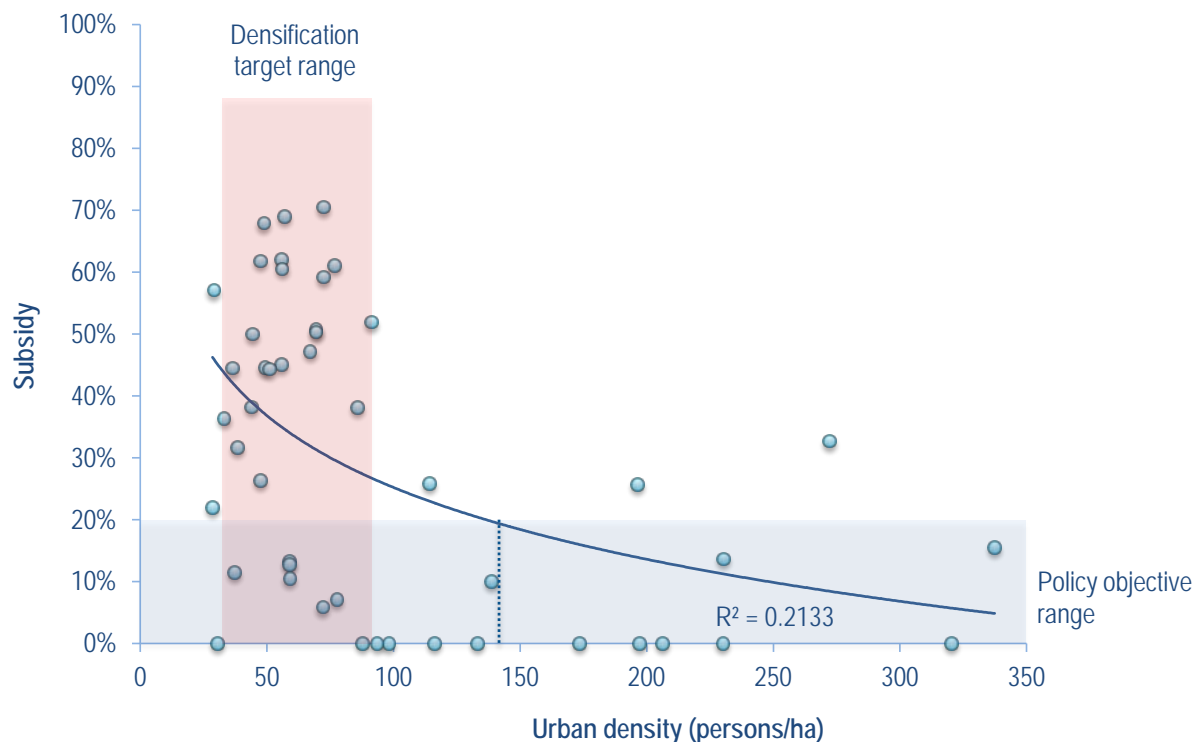

Figure 3:   *Operating cost subsidy and urban density relationship in cities with public transport motorised mode share of more than 15% (n=47)*

The final relationship analysed is between urban density and monthly household expenditure on transport, illustrated in Figure 4. Again, the R^2 values show that the relationship is not as strong as mode share but a downward trend with increasing density is observable. The higher GDP/capita of developed world cities means that all of their monthly expenditures on transport are relatively low, which reduces the significance of its change with increasing urban density. The indicator of monthly expenditure could also be affected by the fare-capping policies of some developed world countries, in which low fares are maintained at low densities by allowing subsidies to increase. Figure 4 displays only the individual plots of developing world cities.

The public transport policy objective states that the monthly household expenditure on transport must be less than 10% of disposable income. Due to the lack of available data, per capita GDP is utilised as a proxy for disposable income. It is acknowledged that the indicators are not directly equivalent, but it is assumed that when aggregating for entire cities and comparing on an international scale, the differences are not substantial. To prevent any user from spending more than 10% of their income on transport, the average household expenditure would have to be considerably less than that. Only two cities have household expenditures on transport of less than 5%, Guangzhou and Shanghai, with urban densities of 119 and 196 persons/ha respectively. The data suggest that the average developing world city would only decrease aggregate monthly household expenditure on transport to below 10% at an urban density of approximately 170 persons/ha.
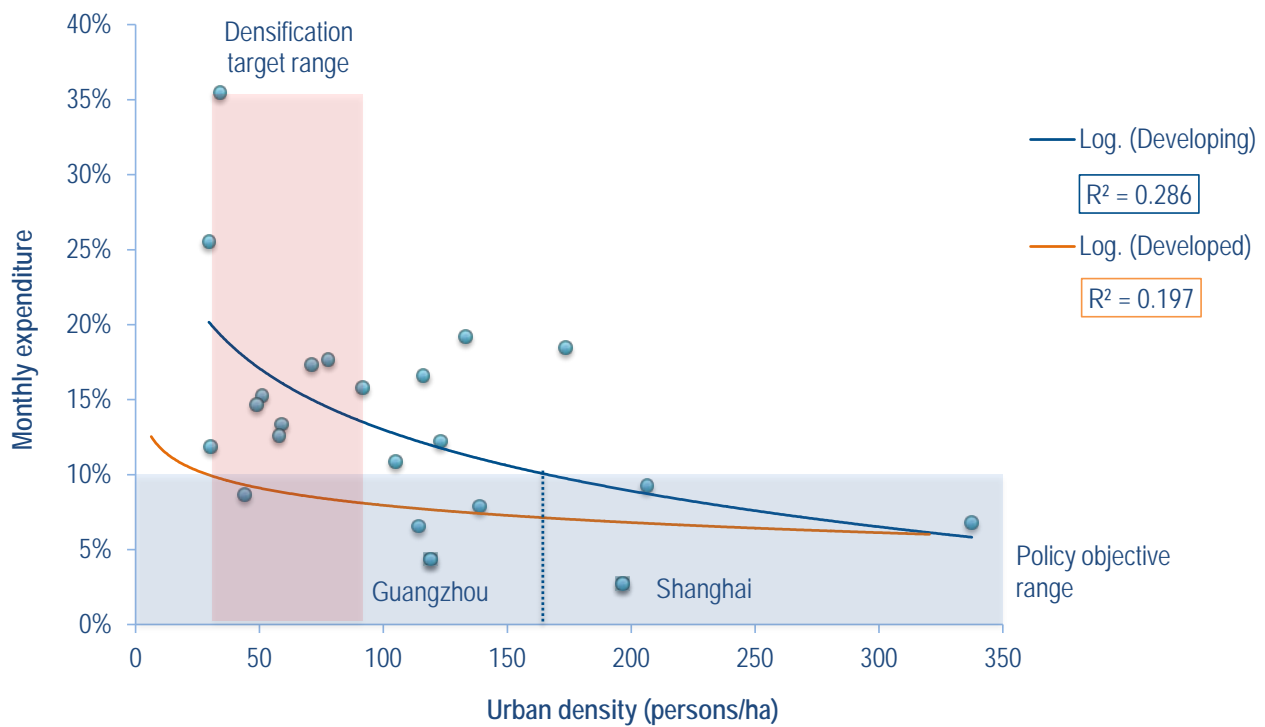
Figure 4: *Monthly household expenditure spent on transport vs urban density for various cities (n=24 developing world cities, n=82 developed world cities)*

4   RESEARCH GAPS

Quantitative, empirical research on the relationships between public transport and urban form is relatively new and evolving rapidly, and consequently there are numerous gaps. Substantially less research has been performed on the relationship between public transport and land use mix and polycentrism, than on urban density. No widely used indicators or measures for these characteristics have been agreed upon and no threshold or benchmark values could be sourced with regard to public transport appropriateness or viability. Consequently, none of the South African cities have set targets for these characteristics. Detailed investigation of these two lines of research could yield similar lessons for land use-transport policy formulation, to those associated with urban density. Within the available analysis of urban density, it should be noted that a significant limitation is the absence of measures of articulated density, which, as argued earlier in the paper, is more important than city-wide urban density in explaining land use-public transport relationships. Further research is needed to develop comparable metrics for articulated density.

Limits on the availability and comparability of city-specific transport data constrain possible empirical analysis. More comprehensive datasets, particularly from developing world cities, would enable a far more rigorous empirical testing of the relationships that public transport networks have with their surrounding environment, than that presented in this paper. In the South African context, more detailed and recurrent household travel surveys would be required to start building the necessary datasets. Additionally, focus would need to be placed on generating land use characteristic measures and targets for each major transport corridor rather than the city as a whole.

5   CONCLUSION

This paper set out to explore the effects of land use characteristics on public transport systems. From a literature review, it was proposed that urban density, land use mix and polycentrism have the strongest connections to public transport efficiency and viability. Notwithstanding the age and skew limitations of available datasets, empirical analysis of international city data suggested that city-wide urban densities in the order of 140-190 persons/ha will be required to achieve the objectives set out in South African public transport policies relating to mode share, subsidisation and household expenditure. The current densification targets determined by South African cities – typically in the order of an increase from current city-wide densities of ±40 persons/ha to ±80 persons/ha – may therefore be insufficiently high to achieve policy objectives. The international data suggest, however, that strategic articulated densities may enable passenger thresholds to be achieved in cities with relatively low city-wide densities. Curitiba, for instance, has a city-wide urban density similar to South African metropolitan cities (±35 persons/ha), yet sustains an extensive unsubsidised public transport network. It is therefore of strategic importance that South African cities focus on public transport corridor densification through proactive transit oriented, land use development, in addition to promoting higher city-wide densities.

Given the data limits that constrain further understanding through empirical analysis, it is argued that simulation research is necessary in order to gain additional insight. The lead author's current dissertation research is seeking to further examine land use-public transport relationships in the South African context through the development of a public transport corridor operating cost model. The model will enable the impact of variations in land use mix, polycentricism and articulated density on public transport viability to be tested. It will also allow testing of the suitability of variations in mode technology choice (e.g. semi-rapid bus vs rapid rail) and network configuration (e.g. direct vs trunk-feeder services) to different urban form patterns. A measure for articulated density will be proposed and new land use targets to meet the South African transport policy objectives will be recommended as a benchmark for a generic transport corridor.

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