

LAND USE DENSITIES AND PUBLIC TRANSPORT IMPACT

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ABSTRACT

In most transport studies, South African Transportation Planners make use of manuals which do not explicitly define the calculation method for trips generated by Public Transport (PT) as a mode of travel, even though this assessment is required in many PT plans.

The author's 2015 SATC-paper investigated the Trip Generation for Public Transport (Onderwater, 2015) and obtained trip generation rates for public transport over a range of activities and income groups. These rates were calculated per person. However, PT-use is greatly determined by the density of people, activities and land use. This paper aims to determine PT trip generation rates per area, focussing on the eThekweni Region.

In order to determine the densities of residential areas, data from the Census 2011 was utilised. For activity areas a telephonic survey was conducted, in combination with measurements obtained using Google Earth, in order to obtain additional information.

The obtained data was then compared with Transit Oriented Development (TOD) policy, which is geared towards creating higher density areas nearby to transit routes. It was found that the densities suggested in the policy are extremely high for the current South African context, and would be unrealistic at this point in time. If these planned densities are used when planning and designing PT systems (as well as other infrastructure), it would result in unnecessary expenditure on infrastructure, which will be oversized and inefficient. It is therefore recommended that planned developments and the associated infrastructure planning should be reassessed. This will ensure maximum use of capital expenditure, and minimise unnecessary operational and maintenance costs.

1 INTRODUCTION

1.1 Trip generation parameters in relation to density

In most transport studies, South African Transportation Planners make use of the Department of Transport (NDoT) *Manual for Traffic Impact Studies*, and the Committee of Transport Officials (COTO) *South African Traffic Impact and Site Traffic Assessment Manual*. These manuals, however, do not explicitly define the

calculation method for trips generated by Public Transport (PT) as a mode of travel, even though this assessment is required in many PT plans.

The author's 2015 SATC-paper investigated the Trip Generation for Public Transport (Onderwater, 2015) and obtained trip generation rates for public transport over a range of activities (residential, education, work and other) and income groups (no/low, middle and high). The trip generation rates were calculated per person, and per average workday.

PT-use is greatly determined by the density of people, activities and land use. Urban Planners would make use of several parameters to calculate these densities, based on experience or policies. This paper's objective is to determine PT trip generation rates per area.

1.2 Scope of this paper

This paper describes different land-use activities and functions, and determines the 'generic' density factors for residential and activity areas: per gross development area (in km²), net developable site area (in ha), building footprint and Gross Leasable Area (GLA, in m²). Once the number of persons per area is known, the potential/estimated use of public transport (PT) can be calculated, using PT trip generation parameters (Onderwater, 2015).

The study for this paper has focussed on the eThekweni area.

2 ANALYSING AVAILABLE DATA

To determine the land use parameters, information is required for residential areas (population) and activity areas (number of workers and visitors), as well as the size of these areas. In this paper density is measured as people per hectare. In other literature density is sometimes referred to as people per km² (which is a factor 100 bigger), or residential units per hectare (depending on household size), or workers per 100m² GLA.

2.1 Information on residential areas

The analysis of residential density is done for the eThekweni Municipality, mainly using the Census 2011 data with population details and area sizes of 'main-places' and 'sub-places'. Additionally some examples of dense hectares were assessed using Google Earth, and the number of units per hectare (100x100 meter) was counted, multiplied with the average household size, approximately equalling the number of people.

2.2 Information on activity areas

On the activity areas, the Census has no information on numbers of jobs and other activities in a specific area. The number of workers and visitors in an activity area can therefore only be derived from the land-use of an area, in hectare or m² GLA, using general parameters.

For this paper, the number of workers and scholars were obtained via a telephonic survey, which was conducted for the eThekweni North region. Additionally the net plot sizes of these institutions was measured using Google Earth. Several large business parks and 30 individual companies, as well as 20 schools were approached. The following questions were asked:

- Address, to match with Google Earth, to measure the net plot size;
- Type of company (manufacturing, warehousing, office, etc.) / school (primary and/or secondary, private or public);
- How long has the company / school been on this address, to assess any difference in density between traditional and more recent developments;
- How many staff, visitors / learners;
- Mode of transport for staff / learners (walking, private car, public transport), to compare with the known parameters.

2.3 Challenges during the survey

The survey was conducted in December 2015 and was addressed to the institution's administrative managers. Therefore it must be assumed the provided answers are as accurate as possible. It was, however, found that many contact persons were busy (due to year-end) and not always fully cooperative, or may have answered the questions in a hurry and therefore less accurately. In particular, when contacting shopping malls and hospitals telephonically, it was found that very few institutions were willing to cooperate; therefore these results were not used.

3 RESIDENTIAL AREAS

In this section the residential land use density is analysed and subsequently the PT trips related to home-based trips (i.e. trips made by a resident) is calculated.

3.1 Residential density

Density of residential areas is determined as population per area size. It depends on the size of the area to what extent 'other' spaces influences this calculation:

- Assessing one cadastral plot of land gives a pure density: how many people live on one plot of land, without taking into account any other land uses. Normally one plot of land would have one household (3-5 people), but could also be several households (e.g. an apartment building, hostel, or additional informal dwellings in the backyard of a township dwelling).
- A hectare of residential area consists of several plots of land and would also have some local access roads. The density calculated based on a hectare is referred to as 'net density'.
- A km² of residential area has access roads and main roads, reserves for bulk infrastructure services, and land in use by other activities such as shopping, commercial, sport, and empty land due to steep slopes and watercourses, etc. The density calculated based on a km² is referred to as 'gross density'. The bigger the area (10, 100 or 1000 km²), relatively more space would be taken by other activities or would be empty, and the lower the calculated average gross density will be.

In eThekweni (one of the densest cities in South Africa, after Cape Town and Johannesburg), a population of almost 3.5 million people live on some 2300 km² (230 000 ha) of land, with an average gross density of 15 people/ha.

Although eThekweni is classified in the Census as a 'metropolitan area', large parts of eThekweni consist of undeveloped land, nature, rural area, agricultural land, industrial areas, port and airport, etc. Almost 700 km² of sub-places are scarcely populated with a density of less than 1 person/ha. Half of eThekweni's sub-places (in total some 1100 km²) have a density of less than 5 people/ha, roughly equals to 1 household per hectare (see figure 1). Therefore it can be assessed that the remaining built-up area of eThekweni (1200 km²) would have an average gross density of almost 30 people/ha.

Within eThekweni there are some large residential areas which are denser. An example is the PINK area (Phoenix, Inanda, Ntuzuma and KwaMashu) which is some 100 km² in size, with roughly 650 000 population; an average density of 65 people/ha. Although the PINK area consists of predominately residential areas, there is some space for other activities such as schools and commercial areas, as well as some empty land.

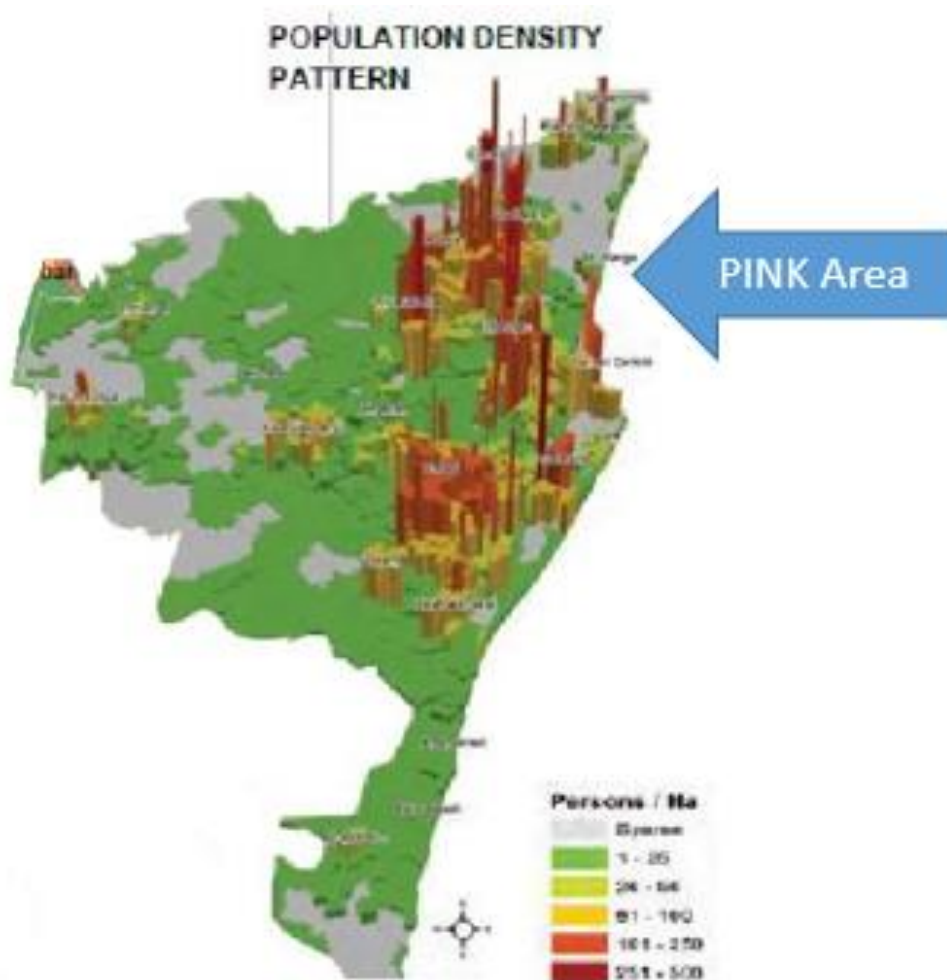


Figure 1: Population density pattern in eThekweni Municipality

KwaMashu, in particular, is some 21 km² in size with 175 000 population, at an average gross density of 80 people/ha. The densest km² in KwaMashu (a sub-place called KwaMashu A) has a gross density of over 250 people/ha.

If you zoom further in, the densest hectares in KwaMashu have a net density of approximately 100 dwellings, equalling to 350 to 400 people/ha. It should be noted that these densest areas are mostly hostels and/or informal settlements, an undesirable type of development. Dense formal places elsewhere in KwaMashu have a net density of some 30 to 40 dwellings, equals to max 150 people/ha (see figure 2).



Figure 2: One net hectare of informal and formal residential areas in KwaMashu, with 350, 250, 150 people/ha respectively (source: snapshots from Google Earth)

Dense areas in eThekweni, however, are scarce; in total 2.3 km² of eThekweni's sub-places have a gross density of over 250 people/ha, and only 44 km² (2%) have a gross density of over 100 people/ha.

3.2 Recent development in densities

Densities change over the years, due to several socio-economic trends and influences:

- The average household size has declined from 3.9 in 2001 to 3.6 in 2011, which has contributed to lower densities. At the same time some houses have been extended, not necessarily resulting in more people living on this plot of land;
- Informal settlements were formalised, which has mostly resulted in lower densities;
- Empty land is developed, which resulted in a greater developed area.

These trends are expected to continue.

The eThekweni area has greatly remained unchanged in size, with a population growth from 3.1 million in 2001 to almost 3.5 million in 2011 (+1% annually). The average gross density has increased from 13.5 to 15 people/ha.

The total size of main-places with low densities (<5 people/ha) has declined from 1300 km² (Census 2001) to 1100 km² (Census 2011), indicating new developments in recent years. The density of the developed part of eThekweni has remained unchanged, or even declined. In 2001, 3.1m people lived on 1000 km², compared to

2011 where 3.5m people live on 1200 km². This indicates a decline of the average density from 31 to 29 people/ha.

Comparison of the 2001 and 2011 Census data shows that the population of the PINK area has grown from 610 000 in 2001 to 650 000 in 2011. This growth in population has occurred with a slight growth of the area size, and hence the average gross density has changed little. Other places that could be compared show that some areas have a lower density (due to smaller household sizes), while other areas have a higher density (due to new developments and up-take of previously empty land).

It can therefore be concluded that the recent growth of eThekweni is mainly a result of an extension of the developed area, and not so much due to an increase in density within existing developed areas.

3.3 Transit Oriented Development

Transit Oriented Development (TOD) is the buzz-word in Land-use and Transportation policy, with higher densities and mixed functions at PT nodes, with the aim of maximising access transit opportunities (Renne, 2009). Both the South African Cities Network (SACN) and the Council for Scientific and Industrial Research (CSIR) cite Pushkarev & Zupan (1977) and mention that a minimum density of 15 housing units per acre (37 units per hectare), equalling to some 150 people/ha, is required for efficient public transport use with a high frequency.

The TOD policy would have little effect on existing areas: the built form is there and would not be re-structured easily. It is more likely that the socio-economic trend, mentioned in the previous section, will continue: smaller average household sizes would result in lower densities and development of some remaining empty plots of land would increase the average density. But on average the density would change little, and slowly.

Densification is relatively easy achievable for new developments on empty developable land. The most recent residential development within eThekweni is in Cornubia. The first phase consisted of 480 units on net 6.5 ha, equalling an average net density of some 75 units/ha, or some 300 people/ha. When taking into account a fair portion of main infrastructure reserve, the gross area is 13 hectare, and the average gross density is 150 people/ha.

The Cornubia Precinct as a whole will consist of 26 000 units, over a total area of 1300 hectares, equalling to a gross density of 20 units/ha, or 80 people/ha. Cornubia however, is planned as mixed land use. Roughly half of the area is destined for commercial and industrial developments, partly due to the fact that it is situated in the noise contours of King Shaka International Airport, where residential development is not advised. Considering this, the average gross density for residential development is some 150 people/ha.

For some parts of Cornubia higher densities are projected. The Cornubia Phase 2 Framework Plan (Iyer, 2015) indicates that certain areas are planned to have net densities of 525 units/ha, or some 2000 people/ha. These areas are positioned along

eThekwini's planned Integrated Rapid Public Transit Network (IRPTN) and it is expected that these areas will generate large volumes of PT-trips.

3.4 Realistic densities

There is limited research which looks exclusively at the impact of culture on density. However, some research does suggest that culture does have an impact on density (Boyko, 2011), and it could also be argued that densities (shaped by numerous factors) have themselves impacted cultures. In Southeast Asia people apparently do not mind living close to each other in high-rise apartment buildings, and densities of thousands of people per hectare are quite common in metropolitan areas. American cities (especially the suburbs) are designed for car use, and are therefore much bigger and less dense. Many people in the Western world apparently prefer a house with carport and a garden for their children to play in, resulting in low densities. Still there are examples of relatively high densities in European inner-cities and new-towns, with 50 to 100 units, up to 200 people/ha, with its positive consequences on transportation.

South Africa currently has low densities, partly due to social-cultural influences, and partly due to apartheid planning.

Traditionally African people come from the rural areas where each house has a yard to grow crops and cattle. After moving to townships and suburbs, they still want that yard (although smaller, and mostly without crops or cattle), resulting in low densities. Another fact is that buildings are 1, max 2 storeys high, also resulting in low densities.

Apartheid planning has resulted in strictly planned townships, with many negative consequences on transportation (and other negativities). But also post-apartheid developments are not very dense. Some 25 units, or 100 people/ha is the traditional standard, and only in recent developments (like Cornubia) higher densities are achieved, but still with gross densities of less than 150 people/ha.

It should therefore be noted that TOD policy densities of 200 or 500 units per hectare / 1000 or 2000 people/ha, are currently not realised anywhere in eThekwini or in South Africa, and can be considered to be in a different league. Such density might be achieved on 'plot'-level (high-rise apartment building), but not on an average net hectare or gross km².

Such densification would therefore need a mind-change: population should accept much higher densities to live in. Such high densities do exist in Asian cities and some European metropolitan areas, but have developed over the last centuries. Can it be expected that this will happen in South Africa within the next two decades?

3.5 Public Transport trip generation

In the author's SATC paper 2015, PT Trip Generation parameters were generated, based on analyses of the National Household Travel Survey (Onderwater, 2015). The average PT trip generation parameter is 0.50 PT-trips per person per day, but this differs per geographical area and income level. These parameters are applied for the above mentioned areas in eThekwini in table 1 below.

Table 1: PT trip generation for residential areas (rounded)

Area	Gross density People/ha	Income level	PT trips per person per day	PT trips per ha per day
eThekwini, total	15	Average	0.50	8
eThekwini, built-up area	30	Average	0.50	15
PINK	65	Low/middle	0.65	40
KwaMashu	80	Low/middle	0.65	50
Cornubia (phase 1A)	150	Middle	1.00	150
Cornubia (residential)	150	Average	0.50	75
Cornubia (planned TOD)	2000	Middle	1.00	2000

With higher densities, a BRT or even Rail system would work well (high density = high patronage = high level of service quality = good cost coverage), where with lower densities smaller transport units (like bus or minibus-taxi) provide a better and more economical service (Vuchic, 1981). With a better PT Level of Service, there is also a strong relationship between density and modal split: with higher densities, the PT share (and also NMT) is much higher than in lower density areas, which are much more car oriented.

4 ACTIVITY RELATED TRIPS

In this section the land use density for activities (working areas and schools) is analysed, and subsequently the PT trips related to activity-based trips is calculated.

4.1 Working areas

Typically when planning for PT in working areas, the number of workers is not known and has to be assumed using calculations based on m² GLA, or even from gross hectares of development. Generally, the conversion factors are based upon urban planning parameters, which need to be calibrated for existing situations, and applied carefully for new developments.

The results from the telephonic survey for individual companies, and the measured plot sizes of these companies, show a net density of 100 to 200 workers/ha. This equals to some 2 to 3 workers/100m² GLA for industrial areas, or even 1 for warehousing activities. Industrial activity buildings normally have a Floor Area Ratio of close to 1 (mostly single storey) and a large portion of empty space around the building.

Analysing Riverhorse Valley Business Estate in northern eThekwini, an industrial and logistic business park developed a decade ago, shows that 173 business companies, with in total some 17 000 workers, are situated on a gross area of 304 ha, resulting in a gross density of just over 50 workers/ha. The Estate however includes large portions of undevelopable land due to a river stream and wetlands, as well as a railway line, the N2 freeway, plus main and access roads. The net total plot development area is just over a third of the Estate's area. This equates to a net density of 150 workers/ha.

Shop and office type of activities would have a higher density of workers/100m² GLA, and such buildings could have multiple storeys. If looking at a net hectare of such developments, some land would not be covered by buildings (e.g. parking, green, etc.). The results from the telephonic survey show a typical net density of 200 to 500 office workers/ha. In high-rise office buildings this can easily increase to 1000 workers/ha.

Analysing La Lucia Ridge Office Estate in Umhlanga (northern eThekweni), developed a decade ago, shows that approx. 290 companies, with in total some 6500 workers (plus 2800 daily visitors), are situated on a gross area of 84 ha, resulting in a gross density of just over 75 workers/ha, or 110 people/ha including visitors. The Estate however includes large portions of undevelopable land due to the hilly nature of the area, as well as some main boulevards and access roads. The net total plot development area is less than half of the Estate's area. This equates to a net density of some 250 people/ha.

These are densities per net hectare. In development plans mostly gross hectares are mentioned and need a reduction factor for coverage, to exclude infrastructure and empty land. Such coverage factor would on average be some 50%.

4.1.1 PT modal split

The survey also included a question on mode of transport to/from work. Although results varied from 100% PT / 0% car, to 0% PT / 100% car, the average of the survey shows roughly a 50/50% split between PT and car (and negligible walking). Apart from the absence of walking trips, the split PT / car is in line with the NHTS national survey and eThekweni's Household Travel Survey.

4.2 Education

Apart from workers (i.e. teachers and other staff), educational institutes attract many learners. Therefore the PT attraction for these 'visitors' has been calculated inclusively.

Results from the telephonic survey indicate that most schools typically have between 500 and 1500 learners, an average of some 1000 learners, plus some 40 staff. Public schools in semi-rural and township areas are on average 1 hectare big (typically between 0.6 and 2 ha). The average density of staff plus learners for public schools is roughly 1000 people/ha.

Private schools are situated on a larger plot of land (predominantly due to the inclusion of multiple sport fields) and have a density of less than 50 people/ha (learners plus staff).

4.2.1 PT modal split

The survey also included a question on the mode of transport used to travel to/from school. The average PT modal split of learners is some 20-25% (including school buses), although it varies between 0% (all walking to township public schools, or all brought by car to public schools) and over 50%. The staff is said to have less than

10% PT use, as most of them drive to school. Apart from the staff results, the modal split of learners is in line with the analyses done from the NHTS, with an average PT trip generation of 0.5: 0.6 for low/medium income, 0.3 for high income areas (Onderwater, 2015).

4.3 Transit Oriented Development

The survey was set up to identify differences for ‘traditional’ areas, as well as for recent developments, where it can be assumed that the new TOD policy would already start to be effective. The results however vary too much to make any conclusion; so it cannot be stated whether recent developments are more or less dense.

It can however be assumed that the type of work opportunities provided in the South African economy would slowly change from agriculture to industrial to services (i.e. primary to secondary to tertiary, and even quaternary economic activities). This would have influence on densities of work places. Industries would typically see buildings of one storey high with lot of ‘empty’ space for machinery and storage of input and output products. Services can be concentrated in offices and would typically see multi-story buildings, with more workers/ha.

Additionally, densification policy could also look at other means to reduce land use per worker, for instance for malls and office parks to develop their parking in basements and not on street level, so as to maximise developable area.

4.4 Public Transport trip generation

Table 2 below has the results of the calculated trips per worker / learner for work places and schools respectively, based on the assessed number of people per net hectare, multiplied with the applicable PT trip generation parameter.

Table 2: PT trip generation for activity areas (rounded)

Area	Net density People/ha	Type	PT trips per person per day	PT trips per ha per day
Working areas	150	Industry	0.8	120
Working areas	300	Office	0.8	250
Prim/Sec schools	1000	Public	0.6	600
Prim/Sec schools	50	Private	0.3	15

5 CONCLUSION AND RECOMMENDATIONS

Applying densities in urban planning should take into account the differences in gross and net densities. When developing several plots of land within a few hectares, one can apply the rates of net density. But as soon as a development consists of tens or hundreds of hectares, space for other land uses would have to be included and the rates for gross densities would be applicable.

5.1 Ultra-high density seems unrealistic

It is assessed that in general residential densities in South Africa are relatively low, with currently an acceptable max of some 100 people/ha. Only in recent developments (e.g. Cornubia) higher densities are achieved, but still with gross densities of some 150 people/ha. Proposed densities of 200 or 500 units per hectare / 1000 to 2000 people/ha, therefore seem very unrealistic, and unachievable currently.

As the high policy densities are questionable, and if PT services are calculated upon these densities, these services would be over-designed. In reality densities would be lower and an oversupply would be designed for. This would also apply for other infrastructure and bulk services. This would result in higher capital expenditure up front, with less return than expected from infrastructure which is oversized and inefficient, and higher than necessary operational and maintenance costs. This in turn would detract foreign or private sector investment, which is required in order to achieve the goals set out in the National Development Plan.

Although the possibility for densification would be less than expected, densification should still be pursued in policy and development, but with more realistic values in the short-term, thus ensuring efficient capital and operational expenditure.

5.2 Mixed use and PT use

Public Transport performs best with high densities, where a high demand of passengers would require a high supply of PT. With higher densities a BRT or Rail system would work well. And with a better PT supply, the quality Level of Service would increase, attracting even more PT passengers.

Public Transport performs even better when it is in mixed use areas: a high density of population plus jobs/activities. Within dense mixed areas firstly people need to travel less (e.g. do their shopping or work around the corner), reducing the need for transportation.

Furthermore, it will also result in a more evenly spread use of the system, with contra-peak and off-peak occupied as well. This will not only contribute to a viable PT system, but also enhance lively cities with many people walking on the street and areas busy throughout the day, and not in peak hours only (SACN, 2014).

The required split between residential and activity related trips is dependent on a number of factors, namely the types of land uses, densities, income groups, etc. When these factors are known, the results of this study can be used to determine what the ideal split is to ensure efficient use of the infrastructure.

6 THE WAY FORWARD

The methodology presented in this paper has been applied for eThekweni only. Additional analyses could be required for other metropolitan areas, and even for towns and rural areas.

The conclusions could also be used for other transportation modes (using COTO and NDoT trip generation manuals), and for the provision of bulk services such as water, sanitation, electricity, etc., in an effort to assist in urban development planning.

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