TOD PRECINCTS SPATIAL RELATIONSHIPS:

Comparing Different Station Precincts of the City of Tshwane

Presented by

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Presented in partial fulfilment of the requirements for the degree of
MASTER OF PHILOSOPHY at the University of Stellenbosch

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Centre for Regional and Urban Innovation and Statistical Exploration

April 2019

Author Declaration

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Date: 9 November 2018

Acknowledgements

Opsomming

Vervoer-georiënteerde ontwikkeling (VOO) neem verskillende vorme aan in verskillende stedelike en inkomstegebiede; dit maak die ruimtelike verspreiding van eiendomsbesit binne gebiede 'n integrale bepalende faktor in die vorming van gebiedsontwikkeling. Hierdie studie het gekyk na verskillende gebiede in verskillende dele van die Stad van Tshwane met verskillende gemiddelde huishoudelike inkomste, en het bevolkingskenmerke en vervoerverhoudings gebruik om uit te lig wat die gebiede verteenwoordig in die periferale en binnestedelike dele van die Stad van Tshwane. Geografiese informasiestelsel (GIS) produkte en tegnieke is gebruik om die verhouding van die verskillende bevolkingsveranderlikes te vertoon en te analiseer, en om gevolgtrekkings te maak rakende die funksionering van gebiede, uitdagings en vooruitsigte vir toekomstige ontwikkeling.

Hierdie studie het gevind dat administratiewe streke 1, 3 en 6 van Tshwane periferale gebiede 'n saamgroepering van besigheids- en kommersiële grondgebruike in die middel van die gebiede het, wat as sentrale besigheidsdistrikte dien. Die regering besit meeste van die nie-residensiële eiendom in die gebiede, en die gebiede self verteenwoordig belangrike kommersiële nodusse vir hulle lae-inkomste subplek lokgebiede. Vervoerverhoudings in hierdie streke is kompeterend, en die toevoeropsies is minimaal. Gebiede in middelinkomste-areas in binnestedelike administratiewe streek 3 verteenwoordig klassifikasie-kategorieë van gebiede met 'n oorvloed van vervoeropsies genaamd middestad, terwyl hooflyn- en toevoeropsies 'n aanvullende verhouding toon tussen die vervoeropsies. Administratiewe streke 1, 4 en 6, wat hoë-inkomste binnestedelike gebiede is, verteenwoordig die stedelike klas en is slegs van waarde vir hulle omliggende buurte.

Die studie het sterk klem geplaas op die bevolkingskenmerke in areas waarom VOO-gebiede geleë is, asook die belangrikheid van gemiddelde huishoudelike inkomste en afstand van die middestad af in die klassifisering, beplanning en ontwikkeling van VOO-gebiede in ontwikkelende lande. Die gebruik van eiendomsbesit en grondgebruik ruimtelike verspreiding help om kern fokusareas uit te wys vir plaaslike beleid en die saamstel van VOO-strategieë en implementering waar belegging in vervoerinfrastruktuur nie bestaan nie. Dit beveel aan dat die integrasie van maniere van openbare vervoer sentraal moet wees tot strategieë vir VOO-gebiede, deur in ag te neem wat die gebiede verteenwoordig vir plaaslike gemeenskappe. Dit beveel verder aan dat die meerderheid van grondgebruik binne die gebiede wat deur die regering besit word, beskikbaar gestel word en dat privaatsektorbelegging in periferale gebiede

aangemoedig word in 'n poging om werkskepping aan te moedig, en om sulke gebiede op te bou tot kern besigheidsnodusse.

Kernwoorde: VOO, binnestedelik, periferale, grondgebruik gebiede, hooflyn en toevoer.

Abstract

In different parts of cities and in different income areas, transit-oriented development (TOD) precincts take a different shape and form, making the spatial distribution of property ownership within precincts an integral determining factor in shaping precinct development. This study looked at different precincts in the different parts of the City of Tshwane with different average household income, using population characteristics and transport relationships to highlight what the precincts represent in the peripheral and inner-city parts of the City of Tshwane. Using geographic information systems (GIS) products and techniques to display and analyse the relationship between the different population variables, inferences were made about the functioning of precincts, challenges and prospects for future growth for the precincts.

This study found that administrative regions 1, 3 and 6 of Tshwane peripheral precincts have a clustering of business and commercial land uses in the middle of the precincts that act as central business districts (CBD). The government owns most non-residential properties in the precincts, and the precincts themselves represent important commercial nodes for their catchment low-income subplaces. Transport relationships in these regions are competitive and the feeder options are minimal. In the inner city administrative region 3, precincts in middle-income areas represent classification categories of precincts with an abundance of transit options called city centre, while trunk and feeder options exhibit a complementary relationship between the transport options. Administrative regions 1, 4 and 6, which are high-income inner-city precincts, represent the urban class and are only valuable to their surrounding neighbourhoods.

The study brought into sharp focus the population characteristics of areas around which TOD precincts are located, and highlighted the importance of average household income and distance from the city centre in the classification, planning and development of TOD precincts in developing countries. Using property ownership and land-use spatial distribution helps to point out the key focus areas for local policy and TOD strategy drafting and implementation where transport infrastructure investment is non-existent. It recommends that central to TOD precincts strategies, should be an integration of public transport modes through acknowledgement of what the precincts represent for the local communities. Furthermore, it recommends that the majority of land uses owned by government inside the precincts be made available, and private sector investment in peripheral precincts shoul be encouraged in an effort to boost job creation and build such precincts as key business nodes.

Key words: TOD, inner city, peripheral, land-use zones, trunk and feeder.

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1   Introduction

The prioritisation of public transportation and access to land takes centre stage in the South African context, with regulations and zoning geared towards transit-oriented development (TOD). Internationally, the study literature notes a similar approach to property pricing and development patterns (Smersh, Smith & Schwartz, 2003; Qvistro & Jens, 2015). These studies on TOD precincts examine whether scrutinising planning history, particularly regarding rural-urban interplay, can differentiate between different TOD strategies and facilitate a discussion on desirable types of future TODs. This study offers an alternative view of TOD in developing countries. It takes an in-depth look at the characteristics and challenges of the TOD precincts in different income areas of a major city in a developing country.

The prevalent local pattern of property development in South Africa still favours one-stand one-house developments in low-income peripheral townships over high-rise buildings, which increases densities; furthermore, the lack of vertical consolidation is thus counter-intuitive (McGaffin, et al., 2015). Starting with the clear demand for well-located, adequate housing and the high rates of urbanisation in cities in the global south, such as in Latin America, Asia and parts of Africa, it is fair to expect that we should be building high and not wide. The TOD model of increasing densities by building high is thus a clear strategy to combat land and housing backlogs, especially in the Gauteng city region in South Africa where urban land is in short supply.

Globally, TOD represents proximity to and a functional relationship with transit stations and terminals, compact mixed uses, and neighbourhoods that encourage walking, cycling and use of public transport by their design within a distance radius of 400–800 m (Suzuki, et al., 2013). This picture of what a TOD precinct should look like is not always the same for every area around the world because of several key factors that affect their formation and development. In developed countries, TOD precincts conform to most of the set criteria mainly due to the socio-economic dynamics and financial muscle of such governments. However, in developing countries such as South Africa, income and class barriers evident in the types of neighbourhoods that different TODs develop sometimes define the dynamics that shape the TOD precincts.

Very few direct studies on TOD precincts exist in the South African context, despite extensive international research (Smersh, Smith & Schwartz, 2003; Qvistro & Jens, 2015; Cervero, Ferrell & Murphy, 2002; Curtis, Renne & Bertolini, 2009). In this study, the vast differences in the characteristics of TOD precincts in the City of Tshwane's are brought to the fore. They mainly include income differences in the different neighbourhoods, which influence the differences in patterns amongst these TOD precincts.

The power of transit is such that it shapes urban development by enhancing accessibility; attributes of land, such as residential and job densities and the degree of land-use mixing, affect travel demand (Suzuki, et al., 2013). Moreover, the benefits related to TODs and public transport include socio-economic integration rather than discrimination, as well as stimulation of the green economy of an area (Graham, et al., 2014). This means that spatial locations, the pattern of property development and the relationships between rail- and road-based public transportation become key in order to realise the deliberate intentions by municipalities to encourage development around public transport, using policy tools such as spatial development frameworks and zoning plans to harness the transformational potential of public transport.

Different TOD precincts exhibit different characteristics and patterns of development, which over time develop differently in terms of the types, quantity and prices of properties. Additionally, the interlinkages between rail- and road-based public transportation also have significant impacts on property development in TOD precincts. Questions remain on TOD precincts, such as how do TOD precincts develop? What property types are prominent and prevalent within TOD precincts? In which parts of the city do TOD precincts work? These questions fuel the need for a thorough study of property development within TOD precincts. Understanding these spatial relationships within TOD precincts is key in the effort to densify and target development as set out by local municipalities.

There is a sense, for example in developing countries, that in low-income peripheral neighbourhoods a certain type of TOD precinct, with low densities and a key but disorganised paratransit system, is emerging. On the other hand, in high-income areas, the TOD precincts' development and evolution seem to conform to the globally accepted TOD criteria. Although existing in the same city, these TOD precincts are different and have a varying urban form.

This study sets out to answer the following questions: 1.) What is the property status around TOD precincts in the City of Tshwane? This is important on a local level as it has the potential to inform service provision. 2.) What is the employment status, income and car ownership

within neighbourhoods where TOD precincts are located? These variables are critical in influencing transport mode choice and affordability. 3.) What is the relationship between paratransit routes and public transport in the peripheral and inner-city neighbourhoods? This is key in determining where there is complementarity and/or competition in the transport system.

It is thus hypothesised that the peripheral low-income TOD precincts represent commercial centres characterised by spatial clustering of commercial properties that are spatially located at the centre of the precincts, developed on land predominantly owned by the state, with minimal trunk and feeder systems. Inner-city high-income TOD precincts, however, represent clustering of different land uses of properties predominantly owned by private investors, with several alternative trunk and feeder systems.

The study focuses on population variables between the different precincts, and attempts to make inferences while using property data to determine land-use type and property ownership. The study will further make inferences about the key factors that allow the different types of TOD precincts to function in their environments despite their varying challenges. The public transport focus of the study and the type of relationship between the paratransit and road-based public transport is inferred based on spatial proximities of routes and stop locations, highlighted by the spatial location of the minibus taxi which represents paratransit and private and city buses, as well as bus rapid transit (BRT) routes as trunk and feeder systems.

The results of this study could thus potentially provide a blueprint for developing countries with similar socio-economic and infrastructure challenges on how to make different types of TOD precincts work. The empirical findings from this study should further provide local governments with a clear picture on how to guide future development investments towards supporting the existing pattern and form of TOD precincts in both low-income peripheral areas and high-income inner-city areas. The results will also highlight available options for a non-conventional model of TOD strategies for low-income areas of both developed and developing countries. The lack of public transport infrastructure investment in developing countries brings into focus the importance and need for a fully functional and integrated public transport system.

2   Literature review

2.1   Transit-oriented Development (TOD)

Transit-oriented Development (TOD) is a mixed land-use development designed to maximise access to public transport and encourage ridership (SAPOA, et al., 2016). Five key identification features define TOD: mixed land-use development; high-density residential housing; a diverse social mix; high-quality pedestrian facilities; and permeable property layouts facilitating pedestrian access (SACN, 2017). For TOD to be effective, pedestrians and buildings need to be closer to public transportation. These normative principles of TOD contradict the sprawling pattern of current cities, where the almost exclusive reliance on private vehicle access is a primary consideration. The reliance on automobiles as a primary journey means to work, shopping and school is not sustainable and has created a love–hate relationship between suburban residents and their beloved vehicles (Freilich, 1998).

The TOD concept is a recent concept that puts forward the three Ds of design/street network, density and diversity. The concept is based on the premise that high residential densities and diversity of mixed land uses would make it more convenient for passengers to use public transport. However, TOD recognises that for high densities and mixed land uses to be successful, public transportation needs to be placed at the centre of urban development (Cervero, et al., 2002). Thus, a more comprehensive definition is "A compact, mixed-use community, centred on a transit station that, by design, invites residents, workers, and shoppers to drive their cars less and ride mass transit more" (Bernick & Cervero, 1997). This must be linked to extensive public transportation feeder systems consisting of pedestrian walkways and transfer systems between the modes to increase the use of public transport (Kamruzzaman, et al., 2013). In Australia the focus on TOD is taken further to categories of TOD precincts (Queensland Government, 2010), and it is pointed out that TOD is not a one-size-fits-all approach and as such can be categorised based on the role they play regionally into six major types: city centre; activity centre; specialist activity centre; urban; suburban; and neighbourhood.

A key feature of TOD is the convenient pedestrian access to local activities from transit services without using a private vehicle. An important issue is how one defines "convenient walk access" – how far will most transit users and potential transit users walk to access transit back and forth to their homes, workplaces, schools, and other non-residential locations? (Crowley,

et al., 2009). The potential willingness of people to walk to access a TOD station determines the geographic extent of a TOD precinct. The distance from the transit is generally defined as being 400–800 meters from a transit station (Suzuki, et al., 2013). The transit station, in turn, is the node that connects village residents to the rest of the region.

Several varying factors affect the choice that individuals make when choosing to reside in a TOD precinct, ranging from access to different modes of transport and amenities to the cost of the property or rental amount, and others. These different factor choices vary for individuals, and they do not hold the same amount of influence factor on factor about the final decision that people make to settle in a certain location (Higgins & Kanaroglou, 2017). There are different TOD bundles with utility-bearing attributes whose influences are spatially defined by a TOD station or precinct catchment area. These utility-bearing attributes are critical in an individual's choice of location within the precinct or catchment area of a TOD, due to the advantages that such areas provide. In turn, the combination of individual utilities in TODs brings additional fare revenue to transit systems, allowing them to provide better services (Bishop, 2015). Furthermore, TOD provides efficient public transport facilities for vulnerable persons such as the young, elderly, poor and the disabled (Curtis, et al., 2009). Informal traders and the informal sector and street vendors also agglomerate in the precinct to take advantage of the increased population densities.

Different factors affect property development within TODs, such as large-scale infrastructure development projects, the proximity of employment nodes, existing residential development in the area, and local regulations. Growth control legislation directly affects property development through their potential to reduce the physical supply of land (Smersh, et al., 2003). Land ownership can also influence urban development – and by extension spatial transformation – because landowners shape the pattern of development and, in particular, the rate of development by deciding to sell or not sell land at a particular time (Halvey, et al., 2017).

2.2   TOD and Compact Cities

TOD dominates discussions across multiple planning platforms globally as most cities look to incorporate an integrated transit-led development system to achieve the idea of a compact city. Transport-centred development is a catalyst for spatial transformation and urban development, and transport intervention provides the accessibility that triggers changes in land use responses

(Bickford, 2015). TOD is based on the principles of city and town layouts developed before the widespread availability of private vehicles (SACN, 2017). The term 'transit-oriented development' originated with the American urbanist Peter Calthorpe in the 1980s, and is closely linked to the New Urbanism movement (Bickford, 2015). In relation to the dispersed nature of today's metropolis and the problems of ecological degradation, traffic congestion, and inequities between wealthy suburbs and poor cities, TOD aspires to promote efficient and sustainable development (such as Smart Growth), advocate compact urban forms and re-urbanise existing city centres. In this sense, these new models represent a 180-degree reversal of the earlier development trends of urban dispersal and low-density suburbanisation (Hirt, 2007). By their design, TODs encourage the establishment of development in nodes around transit stations in relation to their size and function.

In European countries, the compact city is often regarded as the most sustainable and least car-dependent urban form. However, planners' ideas about more compact built environments do not only refer to inner-city densification in relatively monocentric cities (Næss, et al., 2017). Several empirical studies done in Europe and the USA indicate that private car use is lower in compact high-density mixed-use neighbourhoods than in suburban low-density neighbourhoods (Schwanen & Mokhtarian, 2005; Frank & Pivo, 1994).

TOD investment can cause population agglomeration at the TOD zones, as the private TOD investment regimes outperform the public regimes in terms of increasing the net social welfare of the urban system (Ya-Ting, et al., 2017). Zoning scheme provisions are used as a mechanism to address patterns of exclusion to formal retail areas, and to create a safer and more inviting environment for public transport users and poorer employees and consumers. Furthermore, the implementation of an urban development boundary has positive effects on the densification of TODs and increased public transport access, reducing distance effects for more even access to public transport for most of the community and providing economic opportunities in different parts of the city (Roux & Augustijn, 2017). It also enables the inclusion of poorer consumers and public transport users in terms of accessibility of retail spaces, and public transport is an important aspect of implementing TODs (Denoon-Stevens, 2016).

TOD is a fairly new concept in the global South. Implementing traditional TOD strategies is difficult as these cities cannot support the structured, subsidised public transport investments around which TODs in the global North are based (Gauthier & Weinstock, 2010). However, certain insights from international research are applicable to TODs in South Africa. Firstly, the

frequency of modal use around TOD precincts increases significantly with their proximity to train and bus stations (Noland & DiPretrillo, 2015). Furthermore, formal trunk and feeder schemes compete directly with paratransit services in cities in the global South, with some of the benefits of paratransit services lost when public transportation services are implemented. However, complementarity is possible between formal transportation modes and paratransit services if the latter undergoes upgrades in terms of operations and business practices, and operates as a supplementary feeder-trunk-distributor. Such complementarity should eventually lead to more equitable and sustainable public transport systems as paratransit operators contribute to the inclusion of the poorest sectors of society in the city (Ferro & Behrens, 2015).

2.3   TODs in Tshwane and South Africa

South African TODs are by definition high-density mixed-use development centred around a bus station, a train station and/or a taxi rank. In the South African context, the developmental conditions of TODs are different from those in the global North because those that mostly use public transport are peripheral residents of the city. Furthermore, South Africa has a fragmented public transport system in which all modes function on separate tickets. The pattern of their properties is such that they use paratransit and bus feeder system to connect to a fixed train station around which a TOD is formed.

However, the spatial location of the different public transit modes leaves room for assumptions about possible synergies and inferences about proximity externalities. When looking at the complete public transport space, it is impossible to make generalised statements about whether paratransit, taxis, and buses compete with or support other modes of travel and formal transit (King, 2015). Whilst paratransit competes with bus transport through head-to-head competition, duplication of routes or by closing the gaps between times of buses and shortening waiting times, it also compliments bus networks by providing essential link services because they have more flexibility, longer service times and a further reach than the conventional buses and trains (Neumann, et al., 2015). Today, the main competition in the taxi industry is not the bus or train systems, but rather private vehicles (Fourie & Pretorius, 2005).

In South Africa, as in many developing countries, paratransit takes the form of privately owned minibuses, providing informal communal transit services along semi-structured routes. Minibus taxis are referred to as a spatiotemporal flexible mode of transport because of their

flexibility in terms of routes and schedules (Roos & Alschuler, 1975). There are several pieces of literature on the taxi industry's relations with other public transport modes in the South African context, but mainly the way they relate to each other as taxi operators with the literature on its ills and the history of instability and killings (Bähre, 2014). After private cars, minibus taxis are the most common transport mode in South Africa (Neumann, et al., 2015). Especially for low-income citizens living in townships and rural areas, minibus taxi services are often the only possibility for mobility. Despite the great importance of the mode, there is very little public knowledge of routes, fares, and the number of minibuses that are operative. The ownership of routes is a highly contested space that is deliberately exclusionary, often resulting in violence (Khosa, 1992).

In South Africa, the success of TOD lies in the success of the integration of the different modes of transport in the peripheral township areas. Population densities in the peripheral township settlements in the city and the use of public transport are already very high; however, residential property development around bus stops, taxi ranks and train stations does not reflect the required property densities that define TODs around the world. This, however, has not diminished the ridership of public modes of transport. TOD precincts thus have the potential to lead the desired spatial transformation and social integration through an integrated public transport system.

2.4   Policy and Legislation Direction

The state of the TOD precincts in South Africa requires a thorough investigation to understand the spatial relationships and growth potential in the different parts of the city. The uniformity in the literature on transportation policies, strategies and regulations all point out the interconnectedness of transport, that of zoning and property development (Walters, 2013). At the localised level, several public transport strategies and plans have gone through the devolution process and are now under the responsibility of metropolitan municipalities. In the municipalities, different policies are geared towards TOD precincts like the MSDF, RSDFs, ITP and TRTSDP densification and intensification guidelines (SAPOA, et al., 2016). The City of Tshwane (CoT) in their compaction strategy noted the role of integrating transportation using transit promotion nodes (TPN) as hubs to maximise densification. They further identified transit promotion zones (TPZ) as potentially being part of high-density zones or corridors

where such zones also incorporate a major transport facility. This point not only indicates the importance of integrated transport, but also the deliberate intentions of the city to actively create and support TOD (City of Tshwane, 2005).

 Local conditions play an important role in guiding TOD in urban systems, thus property development with the reduction of sprawl is prioritised (Bickford 2015; Wilkinson, 2006). In their Integrated Transport Plan, they found that the fragmentation of individual strategic documents and policies amongst the different stakeholders result in failure to integrate the system. In an attempt to lead the process, the Public Rail Agency of South Africa (PRASA) took the initiative in 2011–2012 to tender most of their properties and developable land surrounding their stations to developers to fast-track the development and redevelopment of property around the stations (SAPOA, SACN & METROPLAN, 2016). Furthermore, the city planned to utilise taxis and BRT buses as feeders for the Gautrain station; it shows a desire for a collaborative transport strategy that works in synergy. The spatial proximity of the three modes is the required catalyst to drive an integrated transport system (SAPOA, et al., 2016).

3   Methodology and Data

The research utilises inferential spatial statistical approaches and employs statistical and geo-statistical tools to study and analyse spatial patterns, thematic map analysis of spatial distribution of land-use zones, and property ownership patterns in the study area.

The study method is used to do a comparative analysis of the spatial distribution of land-use zones and property ownership patterns in peripheral and inner-city precincts. Household income, employment and car ownership data within precincts and precinct catchment areas are compared for the inner city and peripheral areas, as well as analysis of the transport options and relationships within precincts. The aim is to use the spatial relationships of land uses and ownership patterns along with transport within precincts, employment and car ownership figures to make inferences about what precincts represent, and how they function in the different income areas.

The study area is made up of the City of Tshwane's Metrorail and Gautrain stations. All fixed-mode rail-based stations form part of the population of station precincts considered for the study. Criteria based on the number of households within the host subplaces, distance from the CBD and active stations apply, so as to remove stations with less than 250 households, and those further than 30 km from the CBD or classified as being inactive. Figure 1 below illustrates the spatial distribution of the precincts and the underlying catchment area subplaces across the study area.

Figure 1: Study Area Precinct Distribution
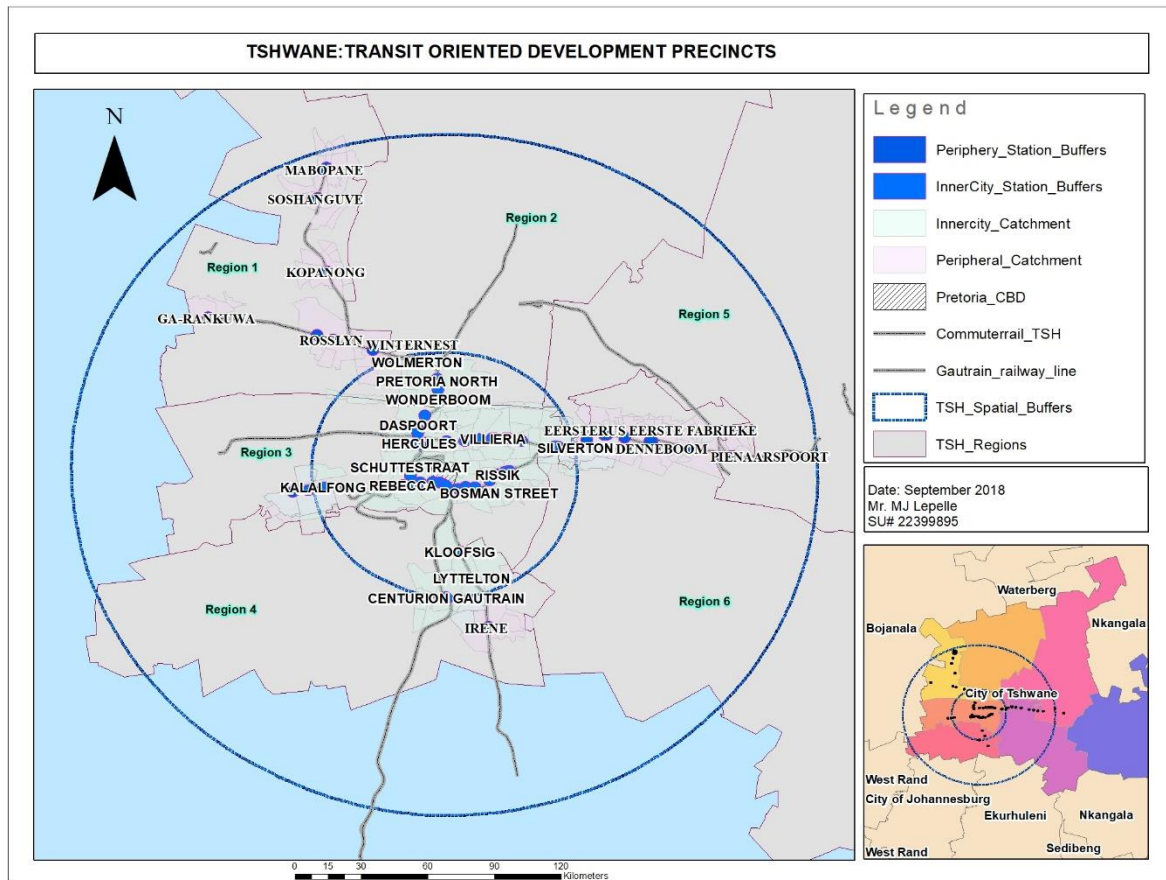
In Figure 1, the station precincts are represented and labelled. They represent 500-metre buffers around stations. The blue rings represent the inner city and peripheral buffers.

The design of the study is to do a comparative study between peripheral and inner-city precincts based on five key elements relevant to the makeup and functioning of TOD precincts. The first analysis is that of household income and car ownership. Household income is important in this study as it relates to affordability for precinct residents of the different modes of transport, as well as give a standing of the socio-economic status of the precinct location. The household income is analysed for each subplace underlying the precinct buffers. Car ownership is seen as an indicating factor influencing the type of transport used, where those with cars do not solely depend on public transport for their commutes and those without cars do. A correlation between income and car ownership will highlight the type of relationship that exists between the two variables based on the strength of the relationship, and will allow us to make inferences about car ownership in each income area and how it relates to the functioning of the precincts.

The second key variable analysed is employment figures in both the peripheral and inner-city precincts and their catchment areas. This variable explains the form and function of precincts based on the employment status of the population. The idea is that precincts with high employment figures represent a different type of precinct to those with high unemployment in terms of affordability of alternative transport modes, and the use of non-motorised transport like walking distances. Employment is represented with graphs for both the precinct subplaces and catchment areas. The output of this analysis will clarify and point out areas that can likely afford the cost of different modes of transport within the precincts.

The land-use zones and property ownership spatial distribution are the third, fourth, and most important variables in this study. They are analysed to explain the makeup and value of precincts derived from the type of ownership group, along with the potential for ease of implementation of TOD-centred local planning strategies. For ease of analysis, the local administrative regions of the City of Tshwane are used to analyse the precinct per admin region, making it easy for the results and recommendations of the study to be useful for regional TOD strategy implementation. The rating categories represent land-use zoning in the data and are classified into 14 different land-use types. Property ownership groups represent the different property owners divided into four major groups of owners. See Tables 2 and 3 below. The results from analysing the distribution and spatial pattern of ownership and land use explain precinct value, type and potential for future growth based on property ownership.

The fifth variables are the trunk and feeder systems and transport mode relationships analysis in both the inner city and peripheral precincts, which are important in explaining the challenges faced by the residents of the precincts and their catchment areas. It also highlights the type of precincts and how they possibly deal with the challenges. The output of the trunk and feeder analysis is an understanding of what kind of transportation is available in the precincts and how the modes of transport relate to each other. The analysis is done using thematic maps of routes and stops, and tables of route types and transport options.

The statistical and geostatistical software used in this study include ArcGIS, SPSS and Microsoft Excel. GIS software was used to capture and standardise different datasets from different sources. Routes data from the City of Tshwane, private bus data sets, valuation roll and cadastre data are some of the data sets that had to be standardised. The geostatistical tool of Getis-Ord General G (Global Statistic) was used for hypothesis testing of clustering of land uses. Clustering is key in the study as it explains one of the key identifying factors for TOD

precincts. The Spatial Buffer tool was used to create all the different size buffers for easy analysis of the data. The buffers include the inner city (10 km) and periphery (30 km), 500 metres for stations precincts and a 2 000 metre buffer for the catchment area subplaces. Several studies on the delineation of the inner city and peripheral do not state actual cut-off distances, however, they point out the characteristics of the inner city in terms of properties, densities, and travel distances while other studies use 10 km from the centre as distance bands to measure footprints. The determination of inner-city delineation in this study of 10 km is supported by the above-mentioned studies, while the peripheral distance of 30 km from the CBD takes into consideration areas influenced by the city centre in terms of daily commutes. Most other studies go further to mention different peripheral areas, including rural-urban interplays (Buchori, et al., 2017).

The study utilised bivariate correlation to measure relationships between household income and car ownership using host subplaces of TOD precincts from 2011 Census data. From the correlation results, inferences are made about the interaction of the population with the precincts. The study utilised property data from the city valuation roll and the City of Tshwane Transport Information Register data, collected through a road-based public transport data update survey conducted in 2013/2014 across the city.

The focus was on the rating categories representing land-use zones and ownership data, which is spatially joined to the municipal cadastre data by using the LIS key codes in both datasets. The Road-based public transport data update survey also provided formal and informal taxi ranks and stop locations within the city, official bus ranks and stop locations within the city that allow for the thematic spatial display of all the locational data of the different public transport feeder systems for analysis. Trunk and feeder system data from the Gautrain management agency is also included. The municipality provides a list of private bus operators and their originating and destination routes inside the different buffer zones. Comparisons of the spatial distributional pattern of all properties, ranks and bus stops in the TOD precincts are done for both peripheral and inner-city precincts in order to make inferences about spatial relationships and development patterns of precincts.

Table 1: Income Categories Groupings

	Low Income				Middle Income		High Income				
1	2	3	4	5	6	7	8	9	10	11	12
	R1-R38 400				R38 401-R153 600		R153 601 or more				
No income	R1-R4 8 00	R480 1-R9 6 00	R9 60 1-R19 2 00	R19 2 01-R38 4 00	R38 4 01-R76 8 00	R76 80 1-R153 6 00	R153 6 01-R307 2 00	R307 2 01-R614 4 00	R614 40 1-R122 88 00	R122 88 01-R2 457 6 00	R2 457 601 or more

The 2011 Census data for household income has 12 different income classes, as per Table 1 above. These study groups are classed into three main household income classes representing low, middle and high income. Furthermore, in order for an area to qualify as a low-, middle- or high-income area, the percentage of households for one category must be 50% or more of the overall households within the subplace when the income category is considered on its own and/or combined with the no-income households category. The income classification of precincts is based on the income classification of the individual subplaces wherein it is located. If a precinct is located between multiple subplaces, the subplace with the majority of properties located within the TOD precinct buffer classifies the precinct.

Table 2: Property Rating Categories Layer or Land-use Zones

Code	Name	Description
1	Agricultural properties	Properties zoned for agricultural practice
2	Business and commercial properties	Commercial properties and office spaces, malls and all retail
3	Educational institutions	All properties zoned for foundation, basic and higher education
4	Independent schools	Independent schools
5	Industrial properties	All mines, firms and other industrial activities inclusive of light and heavy industries
6	Municipal property	Municipality-owned properties
7	No category	Not categorised properties
8	Non-permitted use	Not permitted use properties
9	Public service infrastructure	Shared properties for public use
10	Public worship	Churches, mosques and other religious properties
11	Residential properties	Residential properties
12	State-owned properties/government	Properties owned by the state, national or provincial government
13	Vacant land	Vacant land
14	Null	Null

Table 3: Property Ownership Groupings

Name	Explanation
Private individuals	Properties owned by individuals
Government entity	All properties owned by any sphere of government, government entity or an SOE
Private investors	Properties owned by private companies, trusts or close corporations
Others	Properties owned by churches and other NGOs, as well as unspecified owners

Table 4: Transit Orientation Typology

Type	Applies to:
City centre	Metropolitan capital with excellent transit connections and established high-density and mixed-use built form.
Activity centre	Activity centres provide a comprehensive range of retail, commercial, services, community services and facilities and other employment opportunities.
Specialist activity centre	Major public and institutional uses, such as hospitals and universities, which generate significant levels of activity and demand for transit from a wide range of destinations. Excludes major retail centres.
Urban	Inner urban areas supported by frequent transit services and well connected to employment hubs and key destinations.
Suburban	Locations with strong development potential, which are oriented to a transit station or corridor with reasonably frequent services, may act as a hub for surrounding suburbs and should provide a range of shops, employment opportunities and community services and facilities.
Neighbourhoods	Locations that offer adequate transit services and have the development potential to support a primarily residential community. Provide a basic mix of uses to meet the needs of the local residents, but should be primarily residential and feature moderate density.

Source: (Queensland Government, 2010)

The study strengths are that, due to the study being at the metropolitan area level, most of the work would be completed to the requisite standard of empirical research and the inferences are plausible. The limitations of the study include unavailable ridership data from PRASA, which would provide a complete picture in terms of the value of a precinct to the local population. The other limitation outside the hands of the researcher is that the taxi industry spatial information pertaining to routes, fares and operators is limited, which is why the survey done by the City of Tshwane is the only available taxi route data and does not provide a complete picture.

4   Analysis

4.1   TOD Precincts

The analysis of the study of the properties' distributional pattern, the evolution of TOD precincts and the role of transport within the TODs starts, firstly, by testing for statistical significance and the distribution of the data as part of hypothesis testing done on the rating categories codes of the TOD properties dataset representing land-use zones. Clustering is significant as land-use zone distribution is expected to be in a clustering pattern for different land uses within precincts; this then provides a basis to study the clustering to see which land uses mainly cluster in which precincts, explaining the type of precincts based on land-use clusters.

In testing for statistical significance, one must test for a pattern of land-use zones within the precincts to test whether there is clustering or dispersal of land uses. This study makes use of the High Low clustering tool (Getis-Ord General G Global statistic), as it is the best tool to analyse the concentration of low and high values of a single data variable across the study area. The study confidence level is set at P = 0.01 for a 99% confidence level that there is significant clustering of property land uses across the study area.

Figure 2: High/Low Clustering (Getis-Ord General G)
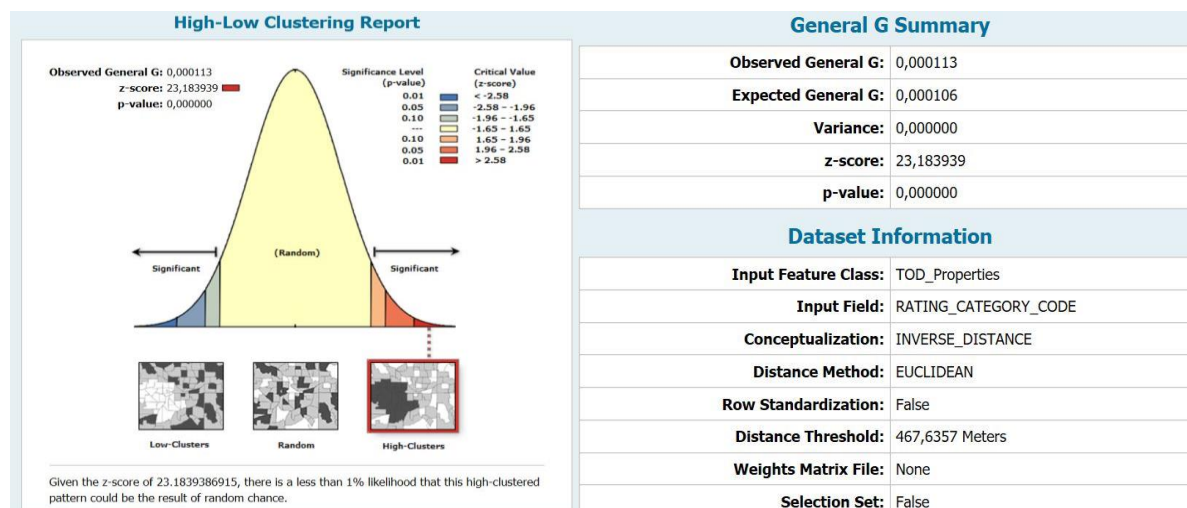

Figure 2 above shows the result of the high/low clustering tool for the TOD precincts properties data across the City of Tshwane. The results show that p-value = 0.00000, which is smaller than the statistical significant p = 0.01; this means that there is clustering of high or low values, the null hypothesis was rejected and the alternative hypothesis accepted. The clustering is

significant in the study as it relates to the type of land uses that are clustered and their location within the precincts, which along with ownership will aid in explaining the behaviour of the precincts, its potential and significance. The Z-score of 23.18 and the Observed General G of 0.000113 being larger than the expected General G of 0.000106 indicates that there is mostly a clustering of high values. This is to be expected across the study area as high rating categories include residential properties (rating category code 11); this means that we expect to see a cluster of residential properties across the TOD precincts in the City of Tshwane.

4.2   Peripheral and Inner-city TOD Precincts Analysis

The peripheral TOD precincts comprise 15 precincts located between a 10 km and 30 km radius outside the Pretoria CBD. These precincts are characterised by low household incomes, high unemployment and a large number of residential properties with less economic activities and limited job opportunities in these precincts and the surrounding suburbs.

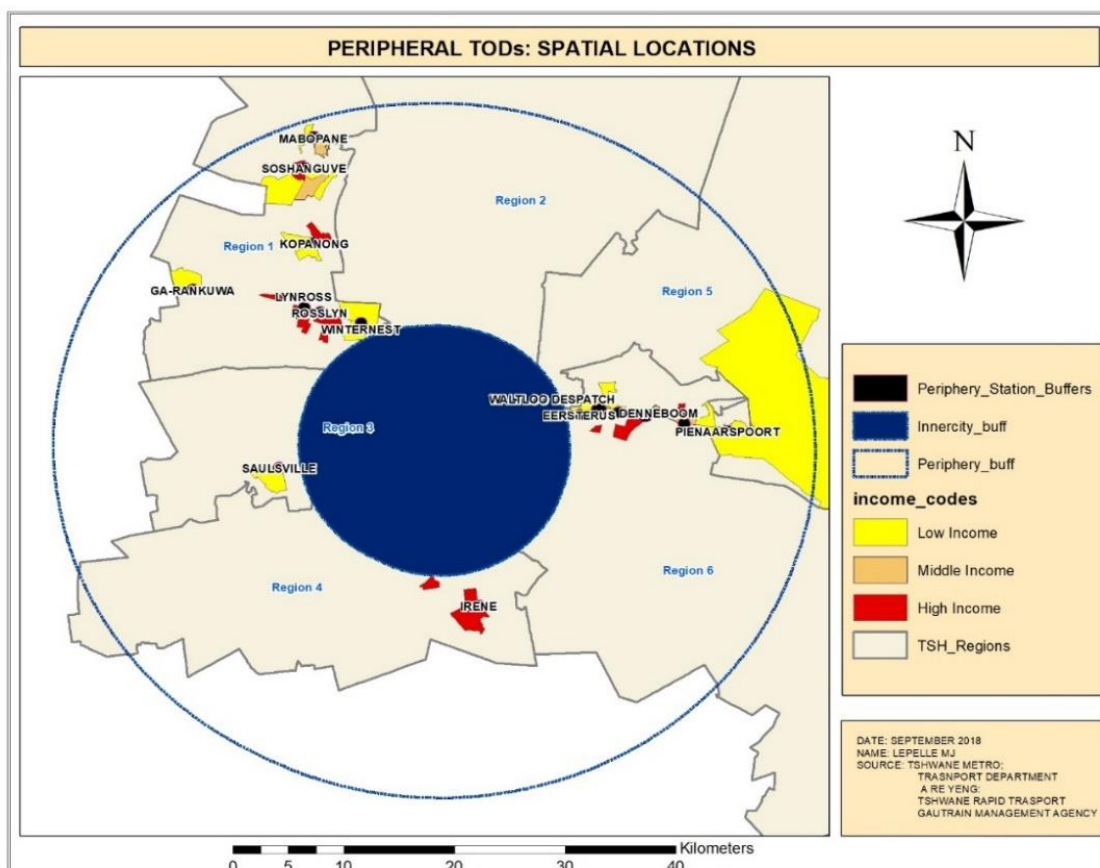*Figure 3: Peripheral TODs of Tshwane*

Figure 3 illustrates the spatial location of the peripheral TOD precincts and their subplaces by income.

The inner-city TOD comprises 33 precincts covering 34 middle- and high-income subplaces; the precincts are located inside a 10 km radius of the Pretoria CBD. These precincts are characterised by high employment levels compared to the peripheral precincts and increased variety of land uses, as well as high economic activities and by extension higher levels of job opportunities in these precincts and the surrounding suburbs in general.

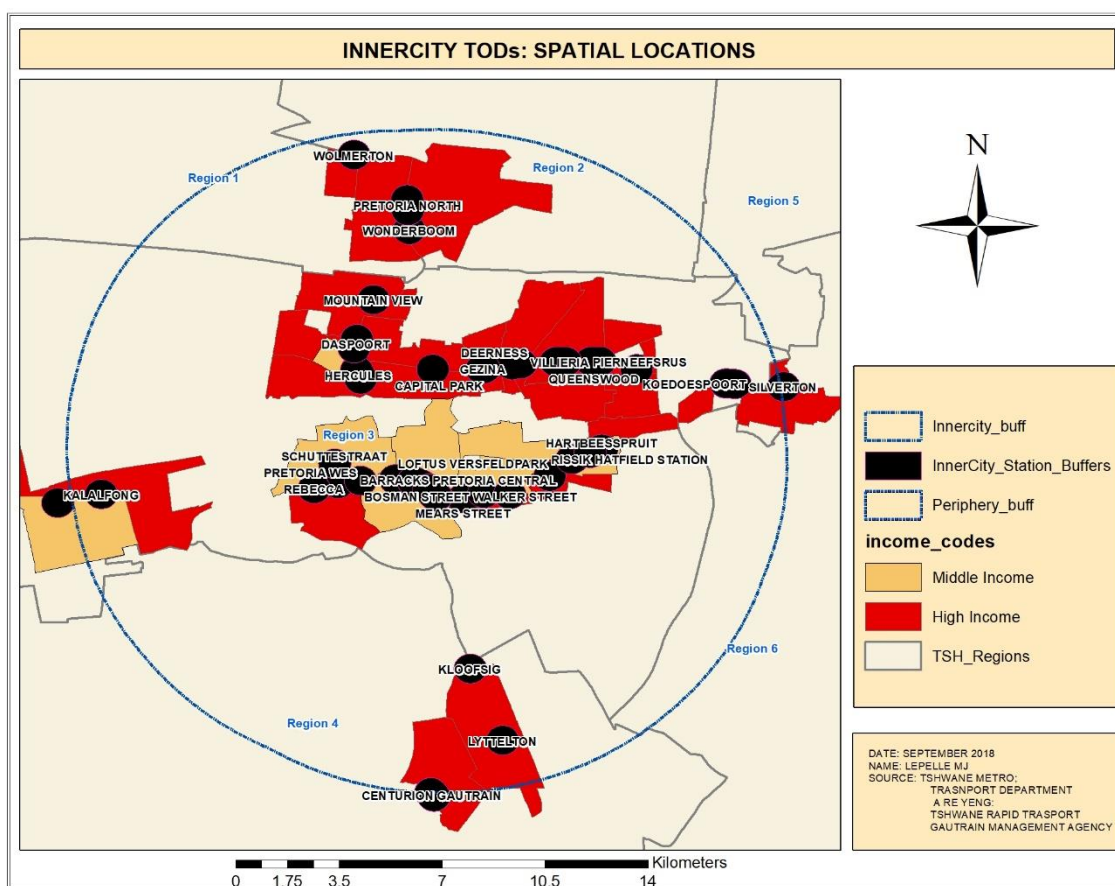*Figure 4: Inner-city TODs of Tshwane*

Figure 4 illustrates the spatial location of the inner-city TOD precincts and their subplaces by income.

4.2.1 Population Variables Relationships

The population variables identified to be most relevant and useful for the study of TOD precincts include household income, car ownership, and employment data variables. The

understanding is that these variables relate to not only the functioning of the TOD precinct, but also to the choice of residential location, choice and use of public transport as well as other available modes of transport, as it is linked to affordability by residents.

Firstly, the relationship between these variables is measured by using a bivariate correlation matrix. This is a less complicated statistical method to test for relationships between variables. The correlation matrix is sufficient to show population variable relationships as it determines whether a relationship exists, the type of relationship, and the strength of such a relationship. Below is the matrix for income versus car ownership in peripheral and inner-city precincts subplaces.

Tables 5a and b: Correlation Matrix Tables

Correlations PERIPHERAL TODs		R1-R38 400	R38 401-R153 600	R153 601 or more	Households with cars 2011	Households without cars 2011
R1-R38 400	Pearson	1	.883**	0,076	.455**	.991**
	Sig. 2 tailed		0,000	0,662	0,006	0,000
	N	35	35	35	35	35
R38 401-R153 600	Pearson	.883**	1	.369*	.739**	.928**
	Sig. 2 tailed	0,000		0,029	0,000	0,000
	N	35	35	35	35	35
R153 601 or more	Pearson	0,076	.369*	1	.885**	0,142
	Sig. 2 tailed	0,662	0,029		0,000	0,416
	N	35	35	35	35	35
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Table 5b

Correlations INNER-CITY TODs		R1-R38 400	R38 401-R153 600	R153 601 or more	Households with cars 2011	Households without cars 2011
R1-R38 400	Pearson	1	.957**	.673**	.645**	.928**
	2 tailed		0,000	0,000	0,000	0,000
	N	34	34	34	34	34
R38 401-R153 600	Pearson	.957**	1	.748**	.685**	.972**
	2 tailed	0,000		0,000	0,000	0,000
	N	34	34	34	34	34
R153 601 or more	Pearson	.673**	.748**	1	.967**	.625**
	Sig. 2 tailed	0,000	0,000		0,000	0,000
	N	34	34	34	34	34
**. Correlation is significant at the 0.01 level (2-tailed).						
*. Correlation is significant at the 0.05 level (2-tailed).						

Table 5a above shows correlation results for the three household income groups against households with cars and households without cars; it indicates that in the peripheral TOD precinct subplaces there is a weak positive (0.455) relationship between households with cars and low-income households (R1–R38 400). However, there is a stronger (0.739) and very strong (0.885) positive relationship with middle-income (R38 401–R153 600) and high-income (R153 601 or more) households and car ownership.

The results mean that most low-income peripheral households do not have private cars, which is thus inferred that they depend on public transport for their daily commute. Likewise, it presents a picture of a lot more car ownership for those living in middle- and high-income subplaces. The inverse is true for households without cars with a much weaker positive relationship between high income (0.142) and much stronger positive relationship between low income (0.991) and middle income (0.928) with households without cars. These numbers are important because the majority of the peripheral TOD precincts are located in low-income subplaces, and by extension can be characterised as such where car ownership is concerned.

In the inner city, as can be seen in Table 5b above, the relationship is such that there is a positive relationship with r scores of 0.685 and 0.972 for middle-income households, and those with cars and those without cars. In high-income households, the relationship is equally positive with r scores of 0.967 and 0.625 for the aforementioned variables.

 However, the strength of the positive relationship differs. It is easy to see that middle-income neighbourhoods have a strong positive correlation with households with cars at r = 0.685, but an even stronger positive correlation with households without cars with r = 0.972. This indicates that in most of these middle-income areas in the inner city, more households are more than likely to be without cars than those with cars. This fact is supported by the strategy to increase public transport options in these areas located in the city interior (see trunk and feeders below).

In high-income TOD neighbourhoods, however, there is a far more positive strong relationship with houses with cars at a correlations coefficient of r = 0.967, while the relationships with houses without cars is lower at r = 0.625.

The spatial classification by income area of the suburbs on which the TOD precincts are located thus become an integral part of this study of peripheral and inner-city TODs. This allows us to make inferences of the functioning of the precincts and their TOD strategies based on the characteristics of these host subplaces.

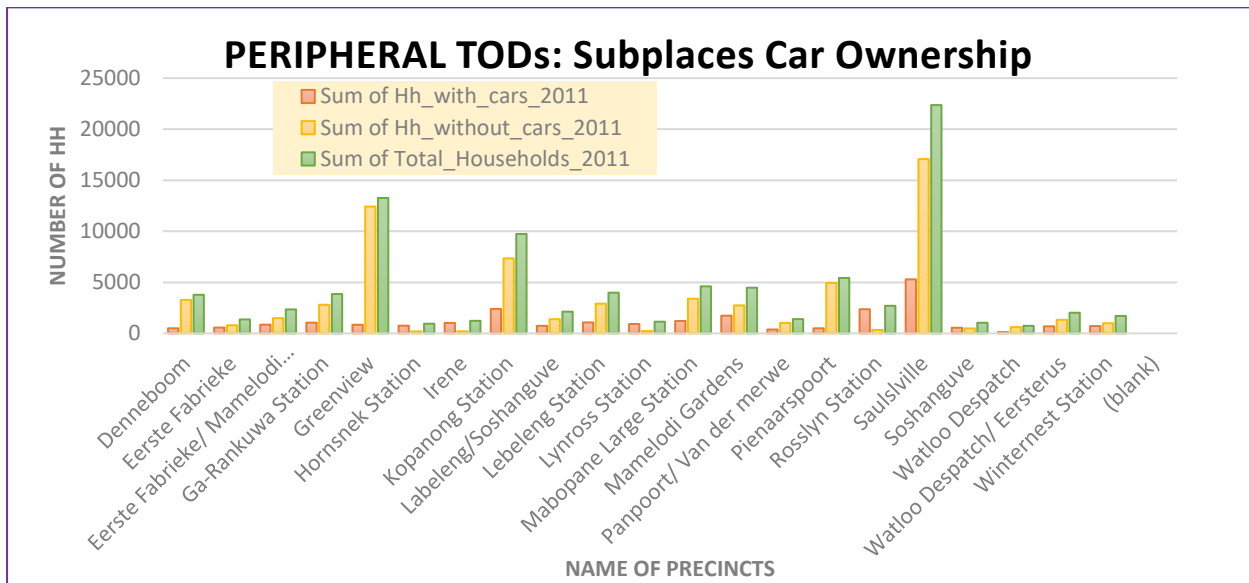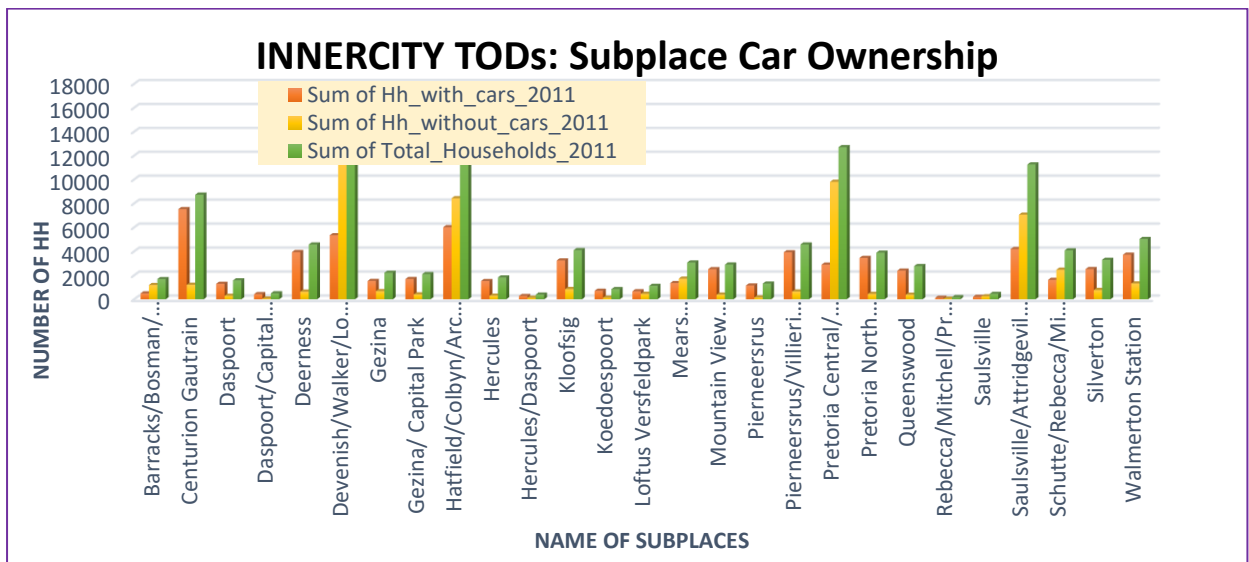*Figure 5a: Peripheral and Inner-city Subplace Car Ownership*

Figure 5b

Peripheral TODs car ownership in Figure 5 above shows that those precincts spatially located in areas dominated by high income and/or economic significance like Irene, Lynross and Rosslyn seem to have a high number of households with cars, while the rest of the precincts are characterised by high numbers of households without cars. This indicates that public transport usage in the peripheral precincts is high mainly in low-income neighbourhoods, where households are mainly without their own private vehicles.

In the inner-city precincts, in Figure 5b above illustrates the car ownership trend that reaffirms the results of the correlation in the inner-city middle-income subplaces in Hatfield at Rissik,

Hatfield, Hartebeespruit and Loftus Versfeld precincts. In Sunnyside at Walker, Cavendish and Mears and in Pretoria Central at Bosman, Barracks and Pretoria and in Pretoria West at Rebecca, Pretoria West, Mitchell and Schuttestraat, households without cars are more prevalent. The high-income inner-city precincts, which are mainly suburb based, have high numbers of households with cars as opposed to those without cars. People in this precinct and their catchment areas thus utilise private vehicles more than public transportation offered in the precincts.

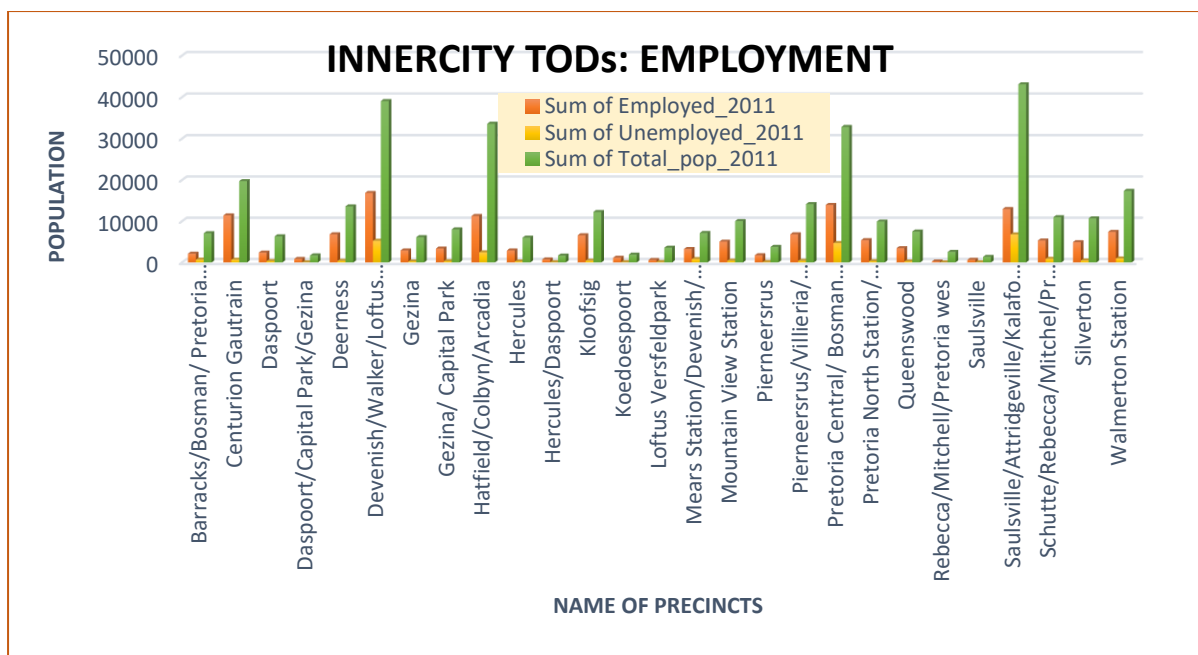*Figures 6a and b: Peripheral and Inner-city subplace Employment*
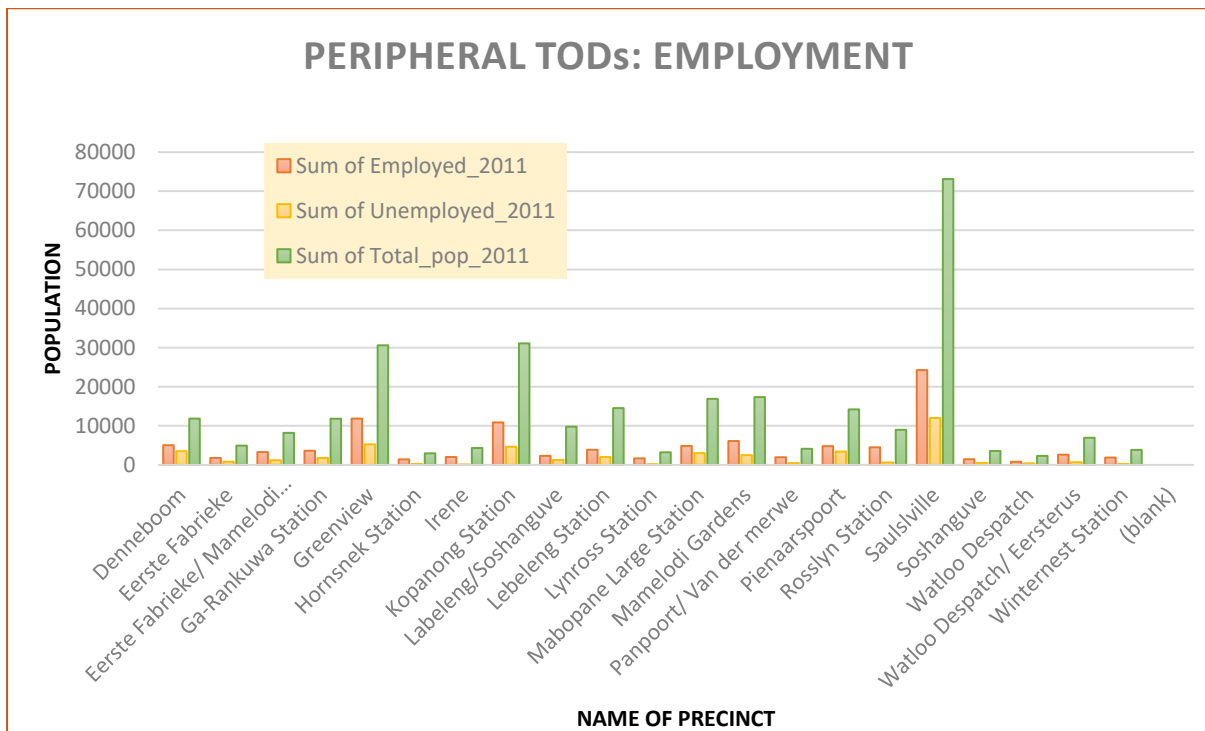
Figure 6a illustrates the employment distribution across the peripheral precincts subplaces, and reaffirms the fact that peripheral low-income precincts are classified by high unemployment, as precincts in Saulsville, Mamelodi and Soshanguve show high numbers of unemployment as opposed to precincts in the inner city. Figure 6b illustrates inner-city employment distribution, showing middle-income inner-city precincts to have slightly higher unemployment while suburb- based high-income inner-city precincts have low numbers of unemployed people. This relates to the functioning of precincts and their role; where unemployment is high, the precincts provide a hub from which to participate in the informal economy sector. In the suburb-based, inner-city high-income precincts the stations merely provide a transport alternative, which – as we saw with car ownership above – is also not overly used by the local residents in these precincts.

4.2.2 Land-use Zones Spatial Distributions

The distribution of land-use zones per precinct within the peripheral and inner city is analysed per administrative region in the city. The city has seven administrative regions, with only regions 1, 3, 4 and 6 housing the active TOD precincts. Regions 2 and 5 precincts are inactive and do not form part of the study whilst region 7 is outside the buffer threshold of the study area. This is important because municipal service provision is broken down into these

administrative regions. Table 5 below illustrates the breakdown of peripheral and inner-city precincts per administrative region in the City of Tshwane.

Table 6: Precincts Representation per Admin Region

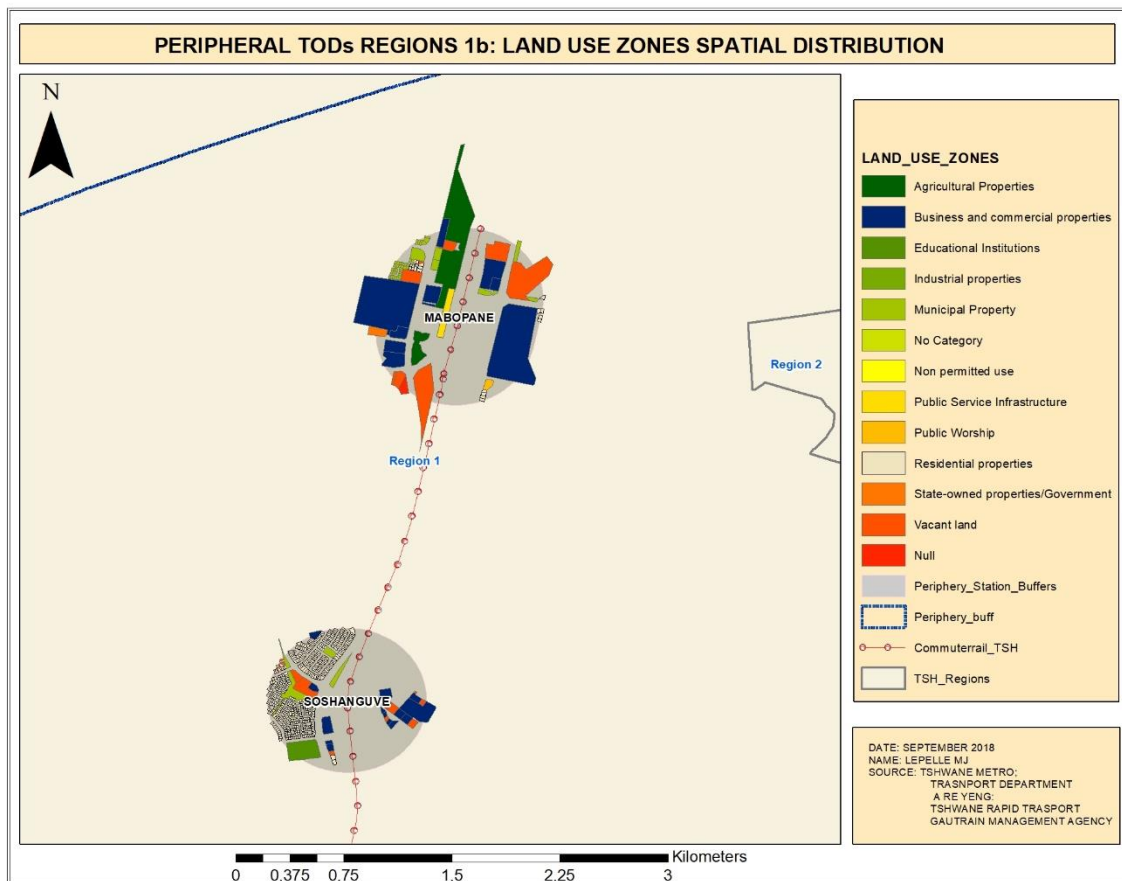| Admin Region	Peripheral precincts	Inner-city precincts
Region 1	Mabopane Soshanguve Kopanong Winternest Lynross Rosslyn Ga-Rankuwa	Wolmerton Wonderboom Pretoria North
Region 3	Saulsville	Atteridgeville Kalafong Pretoria West Rebecca Schuttestraat Barracks Mitchell Pretoria Central Bosman Mears Cavandish Walker Loftus Versfeld Rissik Hatfield Hartebeespruit Mountain View Daspoort Hercules Capital Park Gezina Deernes Villieria Pierneefsrus Koedoespoort Queenswood
Region 4	Irene	Gautrain Centurion Lyttelton Kloofsig
Region 6	Waltloo-Despatch Eersterus Denneboom Mamelodi Gardens Pienaarspoot Eerstefabrieke	Silverton

Figure 7: Land-use Zones Distribution Across Admin Regions

PERIPHERAL: LAND-USE TYPE ACROSS REGIONS

INNER CITY: LAND USE ACROSS ADMIN REGIONS
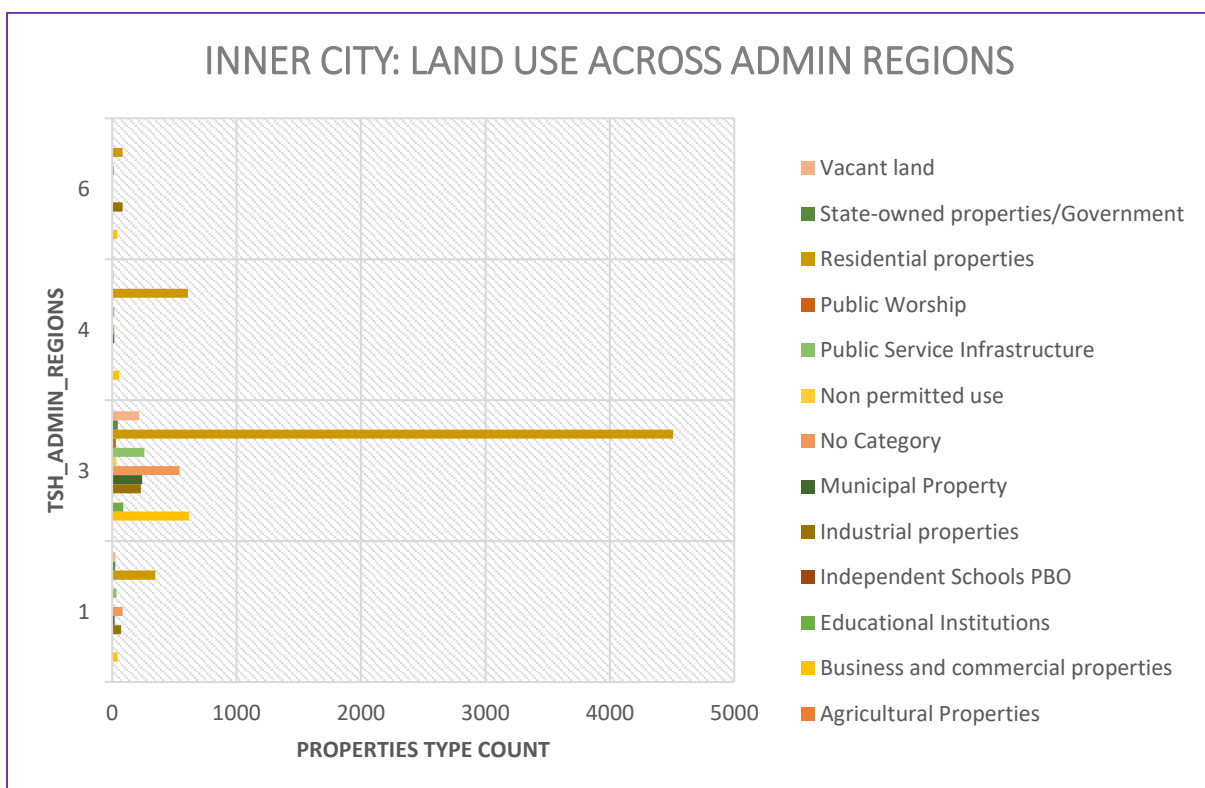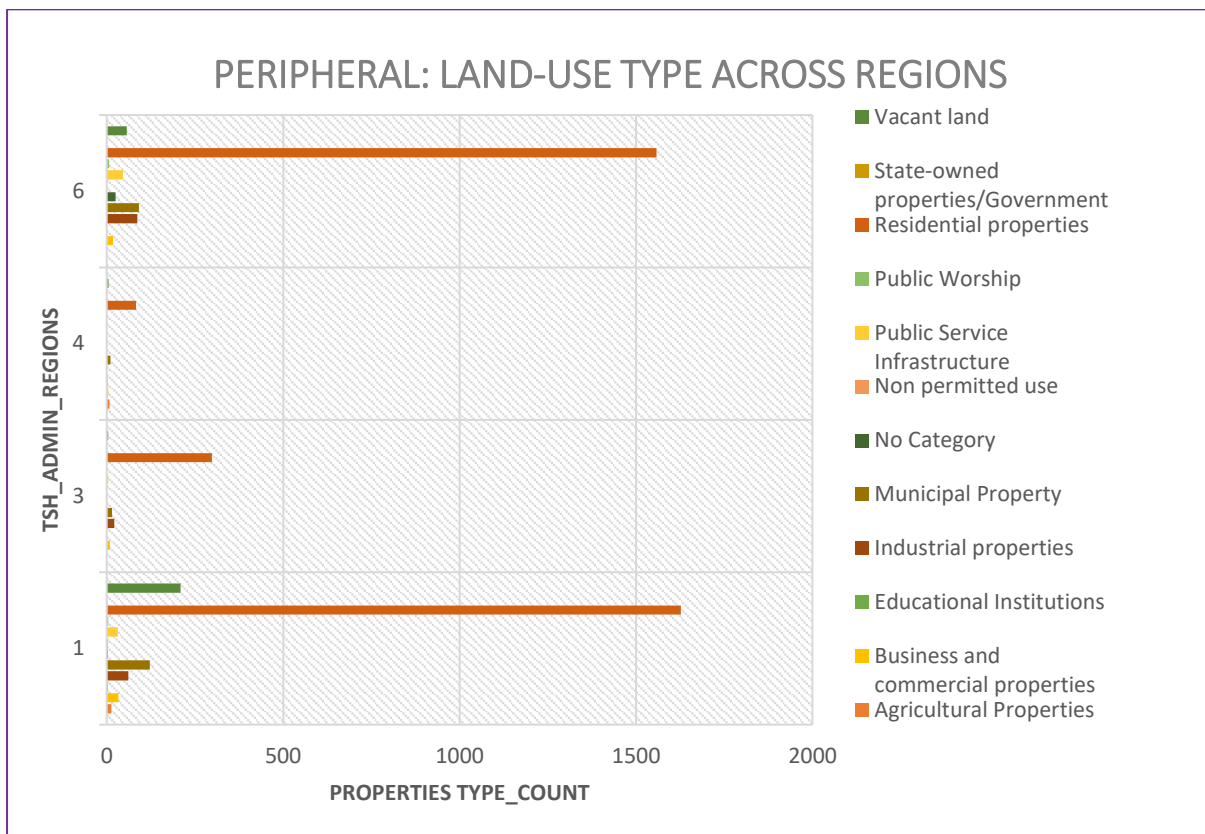
4.2.2.1 Region 1 Land-use Zones

The distribution of precinct land-use zones across the regions shows that in the peripheral precincts in region 1, vacant property is the second most well-represented land use after residential properties, with industrial and municipal land use better represented than agricultural and business properties. In inner-city region 1, however, properties show no category and industrial properties as the second highest behind residential, which is not as well represented compared to peripheral region 1. The spatial distribution of these land-use zones – as seen in the region 1 maps below – illustrates that in peripheral region 1 precincts, business and commercial properties are located centrally while in inner-city region 1, business and commercial properties seem to cluster over a larger area and mix with other land uses.

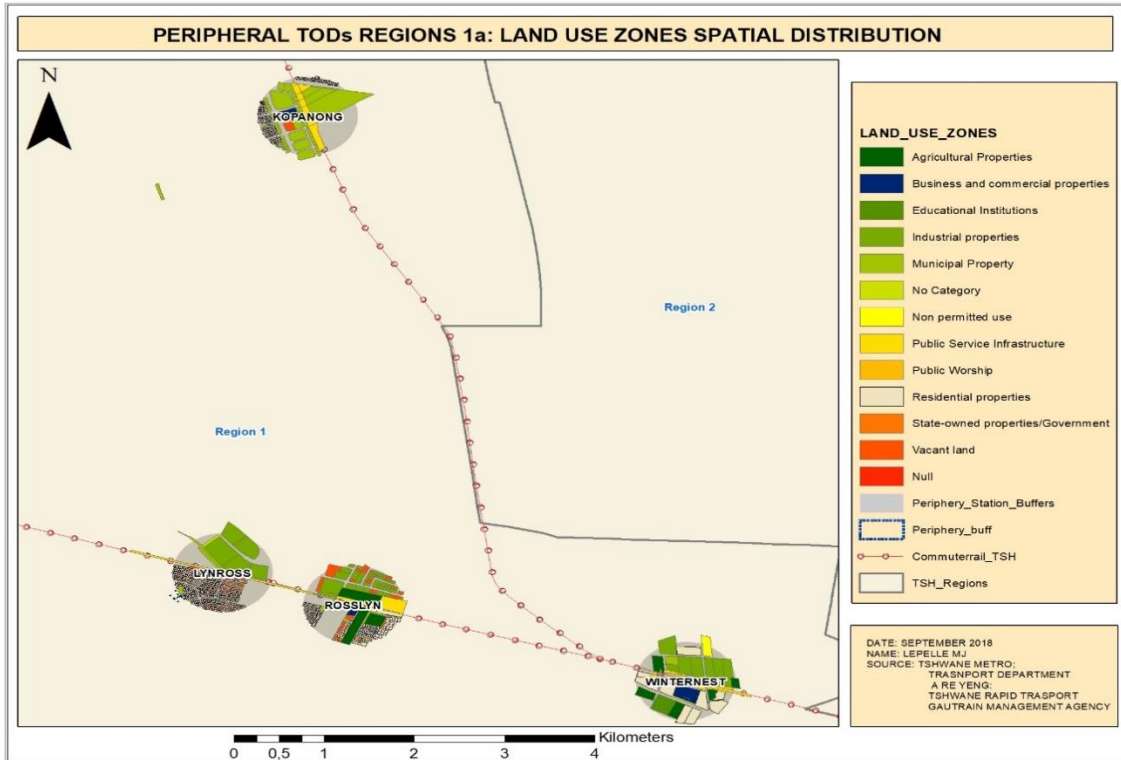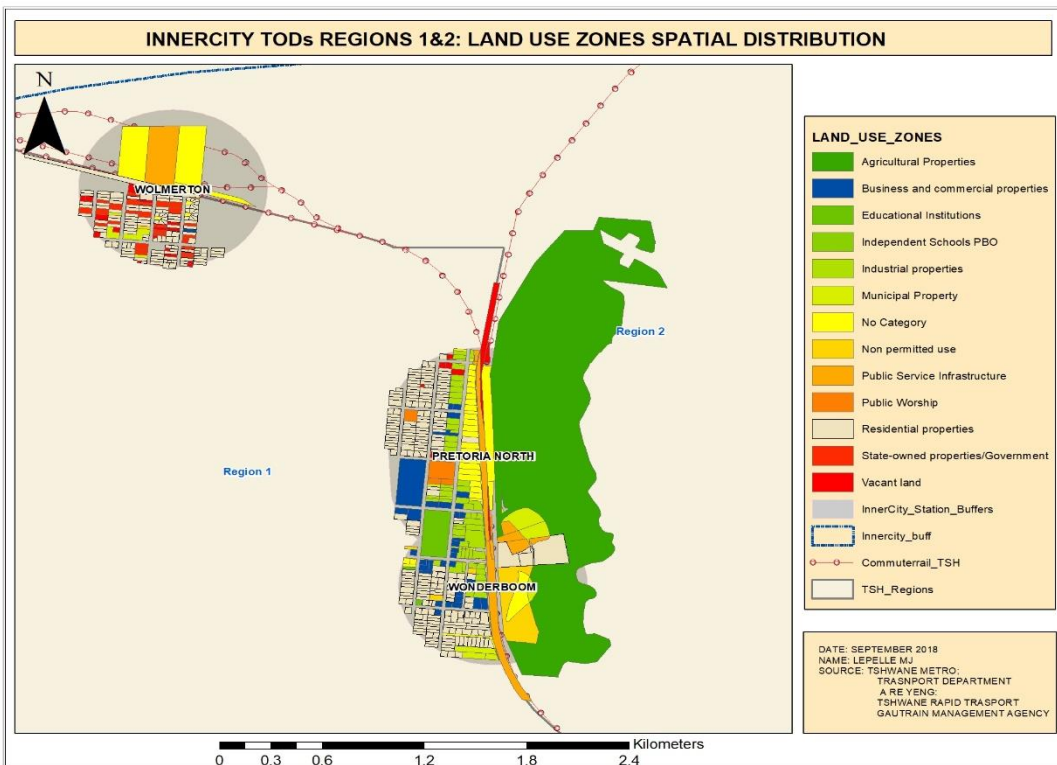*Figure 8: Region 1 Peripheral Spatial Distribution Land-use Maps*

Figure 9: Region 1 Inner-city Spatial Distribution Land-use Map

4.2.2.2   Region 3 Land-use Zones

In region 3 in the peripheral precincts, as seen in Figure 7 above, the precinct is reaffirmed as a residential suburb with almost no existence of other land uses, apart from municipal and some industrial properties. Inner-city region 3 represents the area covering most of Pretoria town, which explains the well-represented land-use mix with business and commercial properties being second highest behind residential, and no category as well as vacant land being well represented.

The spatial distribution of the land uses across precincts, as seen in the region 3 maps below, also distinguishes the type of TODs that are associated with land uses between the peripheral and the inner city. The region 3 peripheral map illustrates a precinct dominated by residential land use with limited commercial activities taking place, while there is a clear potential for future development due to the available vacant land within the precinct. The inner-city region 3 maps, due to their mix in land-use, point to a more traditional type of TOD with mixed land uses. These precincts' growth potential is through redeveloping of existing properties, which is highly influenced by property ownership. In this region, although well developed in some of the inner-city precincts, the state owns a fair share of properties which makes it easy to redevelop to meet targets set out in RSDFs See region 3 ownership below).

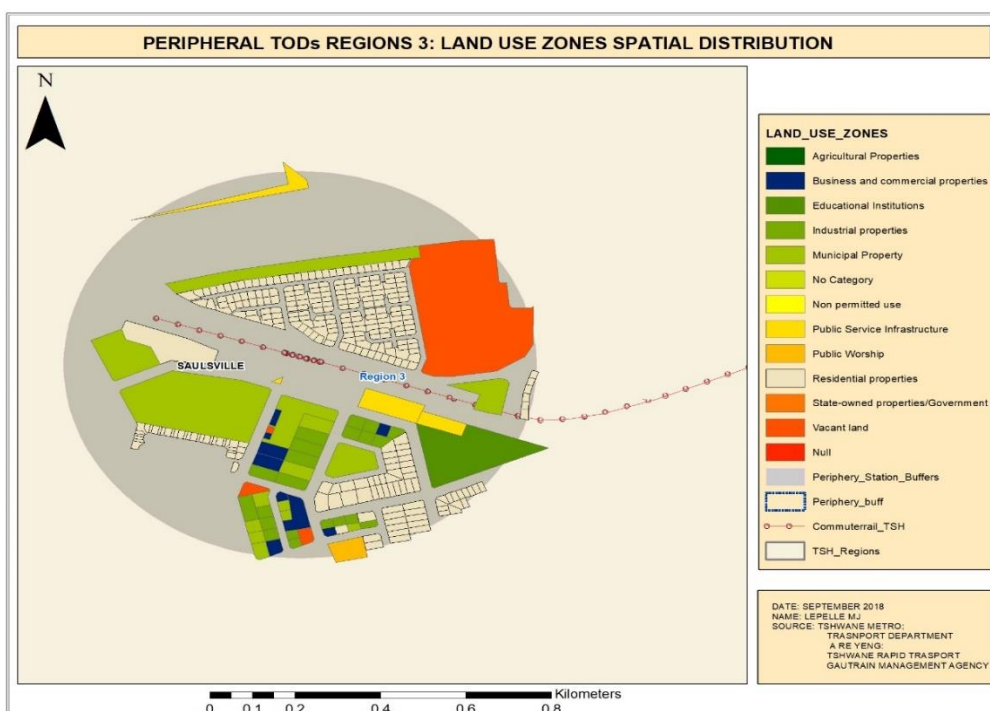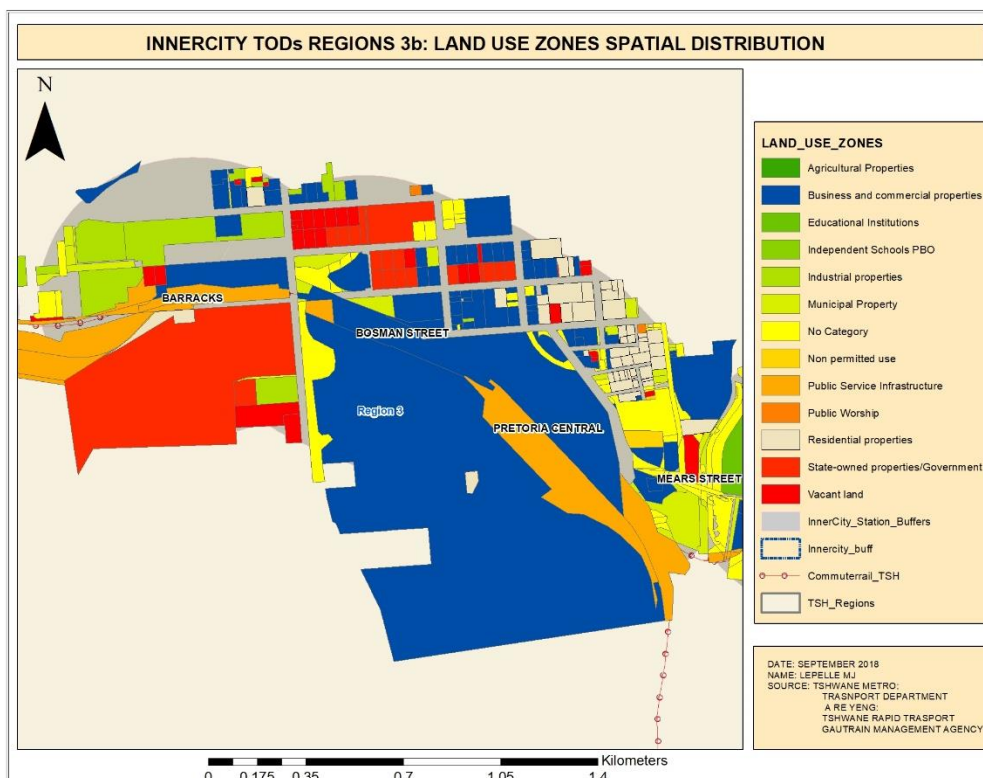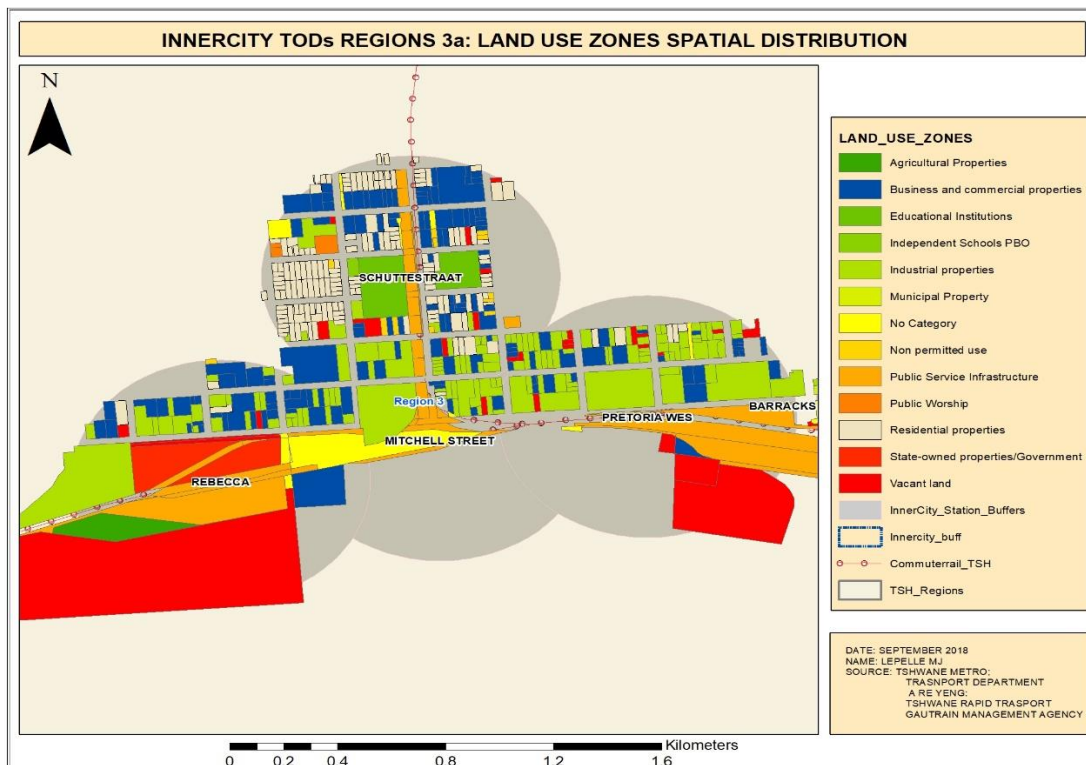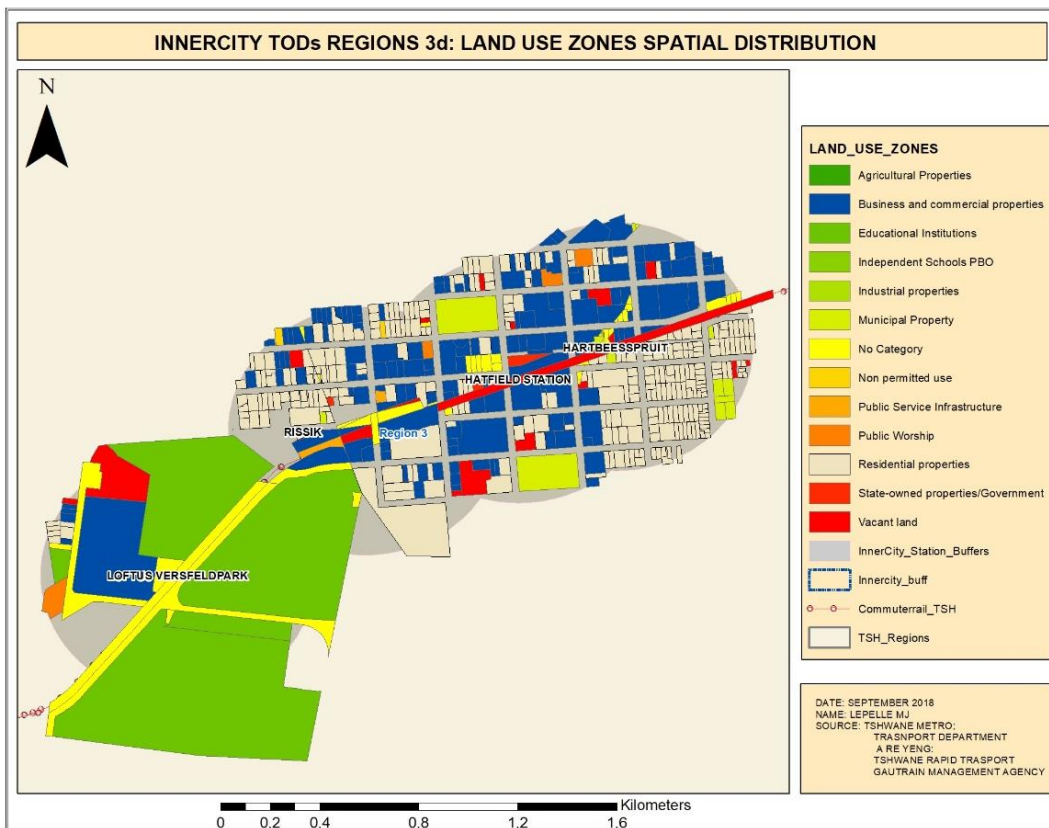*Figure 10: Region 3 Peripheral Spatial Distribution Land-use Map*

Figure 11: Region 3 Inner-city Spatial Distribution Land-use Maps

INNERCITY TODs REGIONS 3c: LAND USE ZONES SPATIAL DISTRIBUTION

LAND_USE_ZONES

- Agricultural Properties
- Business and commercial properties
- Educational Institutions
- Independent Schools PBO
- Industrial properties
- Municipal Property
- No Category
- Non permitted use
- Public Service Infrastructure
- Public Worship
- Residential properties
- State-owned properties/Government
- Vacant land
- InnerCity_Station_Buffers
- Innercity_buff
- Commuterrail_TSH
- TSH_Regions

DATE: SEPTEMBER 2018
NAME: LEPELLE MJ
SOURCE: TSHWANE METRO;
TRASNPORT DEPARTMENT
A RE YENG:
TSHWANE RAPID TRASPORT
GAUTRAIN MANAGEMENT AGENCY

Kilometers
0   0,175 0,35   0,7   1,05   1,4

INNERCITY TODs REGIONS 3d: LAND USE ZONES SPATIAL DISTRIBUTION

LAND_USE_ZONES

- Agricultural Properties
- Business and commercial properties
- Educational Institutions
- Independent Schools PBO
- Industrial properties
- Municipal Property
- No Category
- Non permitted use
- Public Service Infrastructure
- Public Worship
- Residential properties
- State-owned properties/Government
- Vacant land
- InnerCity_Station_Buffers
- Innercity_buff
- Commuterrail_TSH
- TSH_Regions

DATE: SEPTEMBER 2018
NAME: LEPELLE MJ
SOURCE: TSHWANE METRO;
TRASNPORT DEPARTMENT
A RE YENG:
TSHWANE RAPID TRASPORT
GAUTRAIN MANAGEMENT AGENCY

Kilometers
0   0,2   0,4   0,8   1,2   1,6

4.2.2.3   Region 4 Land-use Zones

Region 4 precincts have the distinct advantage of being located in a part of the city that has high average household income for both peripheral and inner-city precincts. In the peripheral precincts, it is purely a residential precinct with no other property zoning showing a significant representation. Inner-city region 4 also shows the prominence of residential properties with higher business and commercial properties representation, illustrating the proximity of the inner-city precincts in region 4 to the Centurion CBD.

The spatial distribution confirms the nature of the peripheral precinct in region 4 with minimal clustering of any activity around the precinct, whilst in the inner city there seems to be a cluster of commercial activities surrounded by residential properties lining the precincts. This pattern in the inner-city precincts in region 4 is indicative of precincts evolving to conform to the international classification of precincts aided by what seems to be the value of land, which is evident by the number of properties owned by private investors see ownership details below).

Figure 12: Region 4 Peripheral Spatial Distribution Land-use Zones

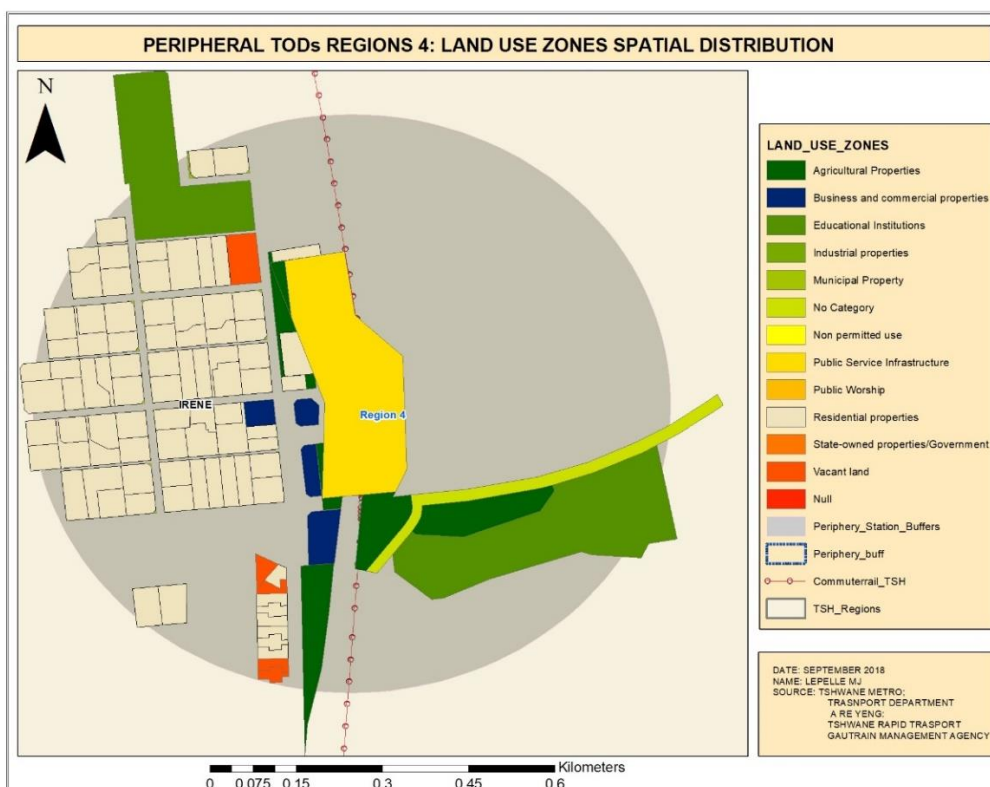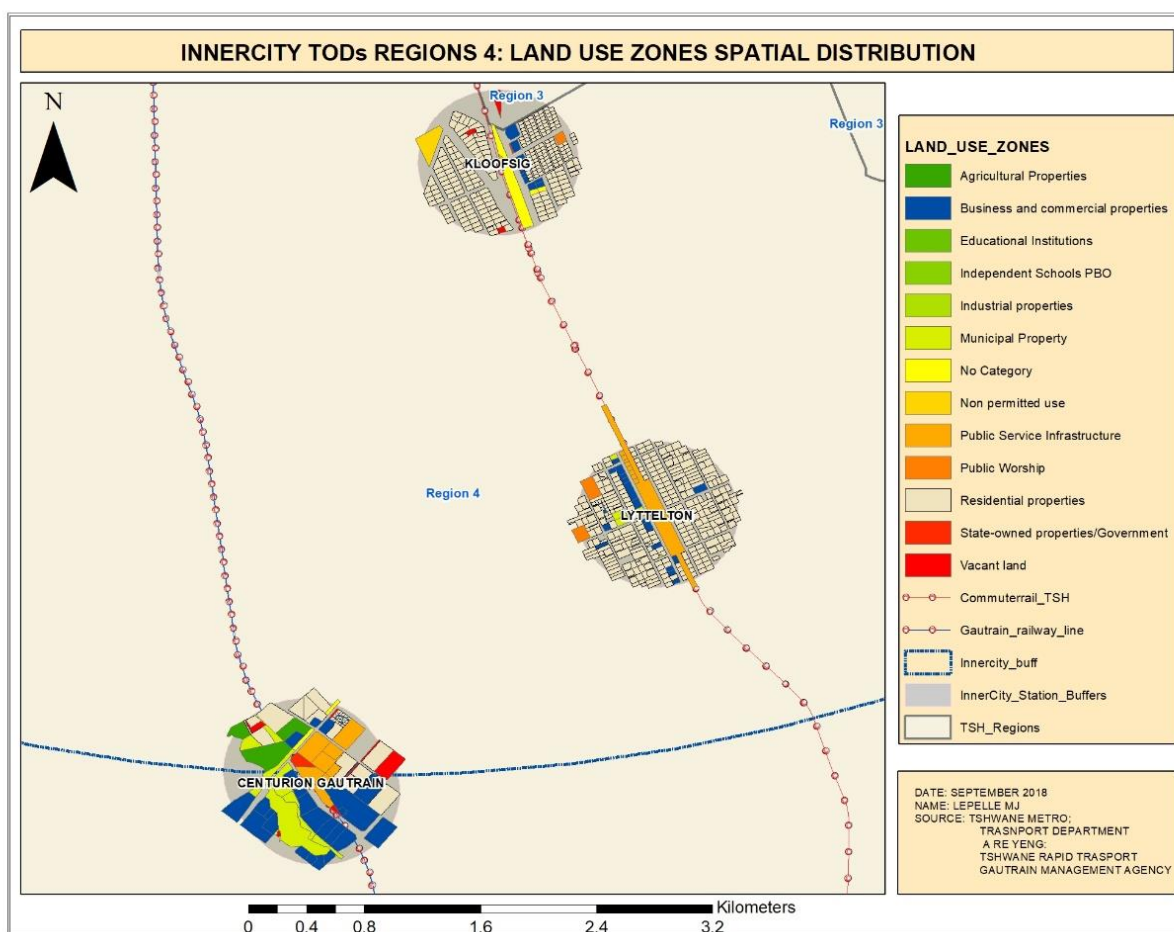*Figure 13: Region 4 Inner-city Spatial Distribution Land Use*

4.2.2.4   Region 6 Land-use Zones

In region 6 in the peripheral precincts, the distribution of property land-use zones paints a picture similar to other peripheral regions where there is dominance of residential followed by industrial and municipal uses, with minimal business and commercial properties. In region 6 in the inner city, the dominant use is industrial, followed by residential use. These precincts show an area of low unemployment as illustrated in the employment graph in Figure 7 above.

Spatially, the distribution of property land uses in the peripheral region 6 precincts illustrates a pattern of municipal and industrial activities converging centrally, offering an opportunity for future development and rezoning by the government as most of the peripheral precinct properties are owned by a government entity. In the inner city, as is the case with other inner-city regions, the precincts in region 6 offer limited potential for growth through greenspace development and shows a large representation of industrial properties.

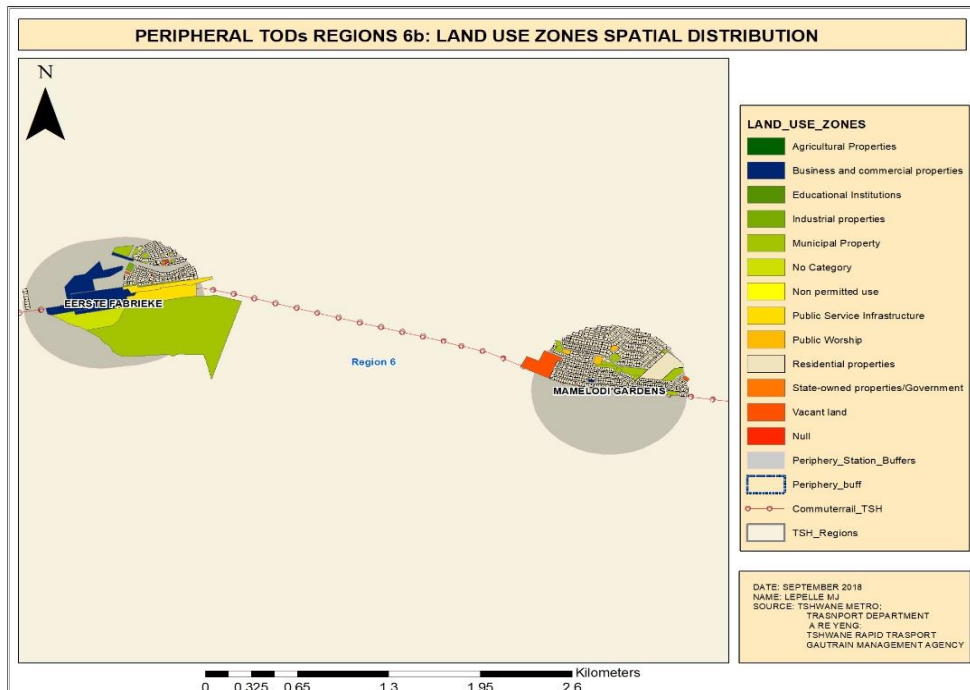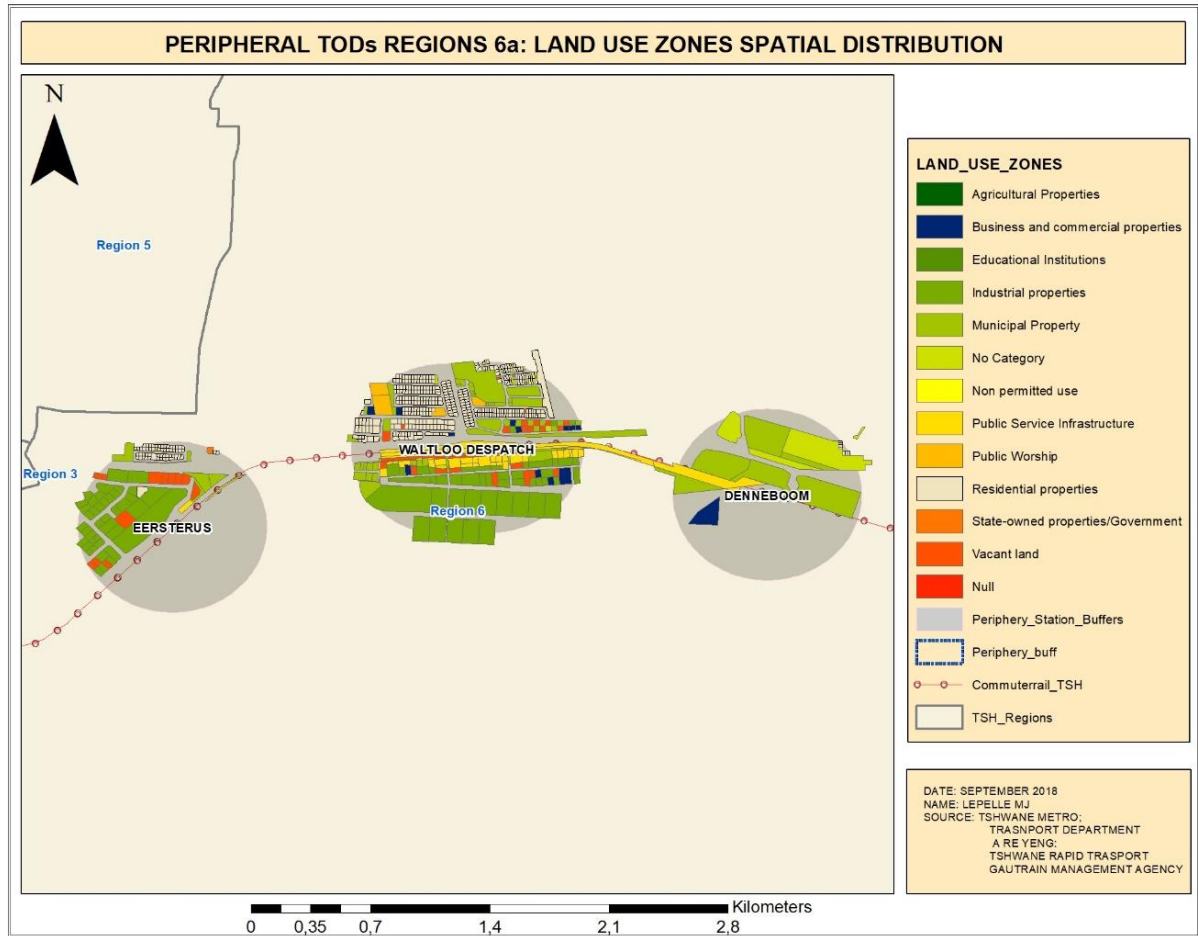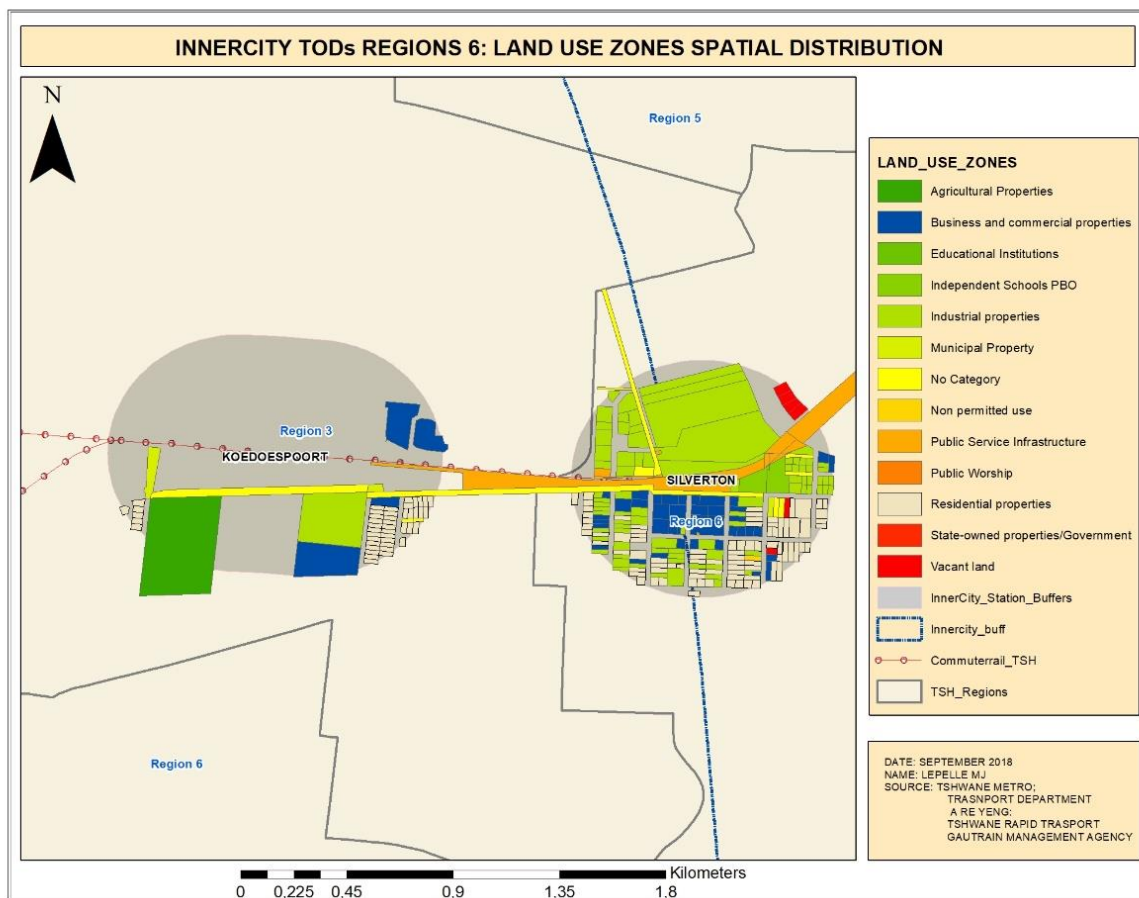*Figure 14: Region 6 Peripheral Spatial Distribution Land-use Zones Maps*

PERIPHERAL TODs REGIONS 6a: LAND USE ZONES SPATIAL DISTRIBUTION

LAND_USE_ZONES

- Agricultural Properties
- Business and commercial properties
- Educational Institutions
- Industrial properties
- Municipal Property
- No Category
- Non permitted use
- Public Service Infrastructure
- Public Worship
- Residential properties
- State-owned properties/Government
- Vacant land
- Null
- Periphery_Station_Buffers
- Periphery_buff
- Commuterrail_TSH
- TSH_Regions

DATE: SEPTEMBER 2018
NAME: LEPELLE MJ
SOURCE: TSHWANE METRO;
          TRASNPORT DEPARTMENT
          A RE YENG;
          TSHWANE RAPID TRASPORT
          GAUTRAIN MANAGEMENT AGENCY

Kilometers
0   0,35   0,7   1,4   2,1   2,8

PERIPHERAL TODs REGIONS 6b: LAND USE ZONES SPATIAL DISTRIBUTION

LAND_USE_ZONES

- Agricultural Properties
- Business and commercial properties
- Educational Institutions
- Industrial properties
- Municipal Property
- No Category
- Non permitted use
- Public Service Infrastructure
- Public Worship
- Residential properties
- State-owned properties/Government
- Vacant land
- Null
- Periphery_Station_Buffers
- Periphery_buff
- Commuterrail_TSH
- TSH_Regions

DATE: SEPTEMBER 2018
NAME: LEPELLE MJ
SOURCE: TSHWANE METRO;
          TRASNPORT DEPARTMENT
          A RE YENG:
          TSHWANE RAPID TRASPORT
          GAUTRAIN MANAGEMENT AGENCY

Kilometers
0   0,325   0,65   1,3   1,95   2,6

Figure 15: Region 6 Inner-city Spatial Distribution Land-use Zones

4.2.3 Property ownership spatial distribution

The distribution of ownership of property across the precincts in the region tells a story of TOD precinct development and potential for further development. The ownership of property for this study is categorised into four major ownership groups: private investors; individuals; other; and government entity.

Figure 16: Peripheral Ownership Spatial Distribution per Admin Region
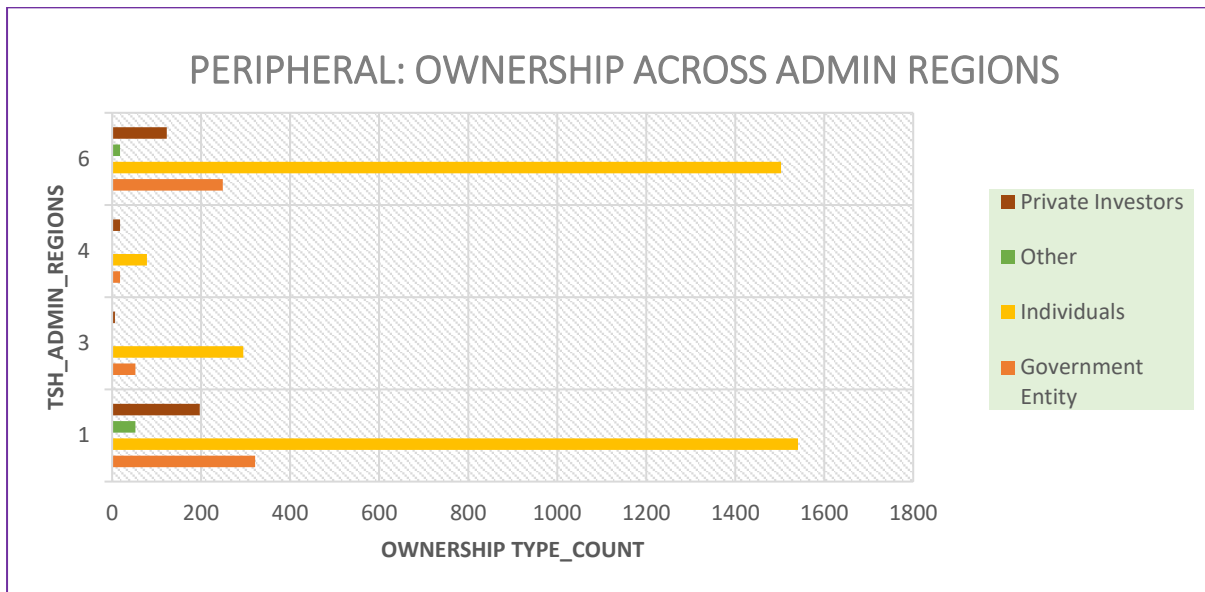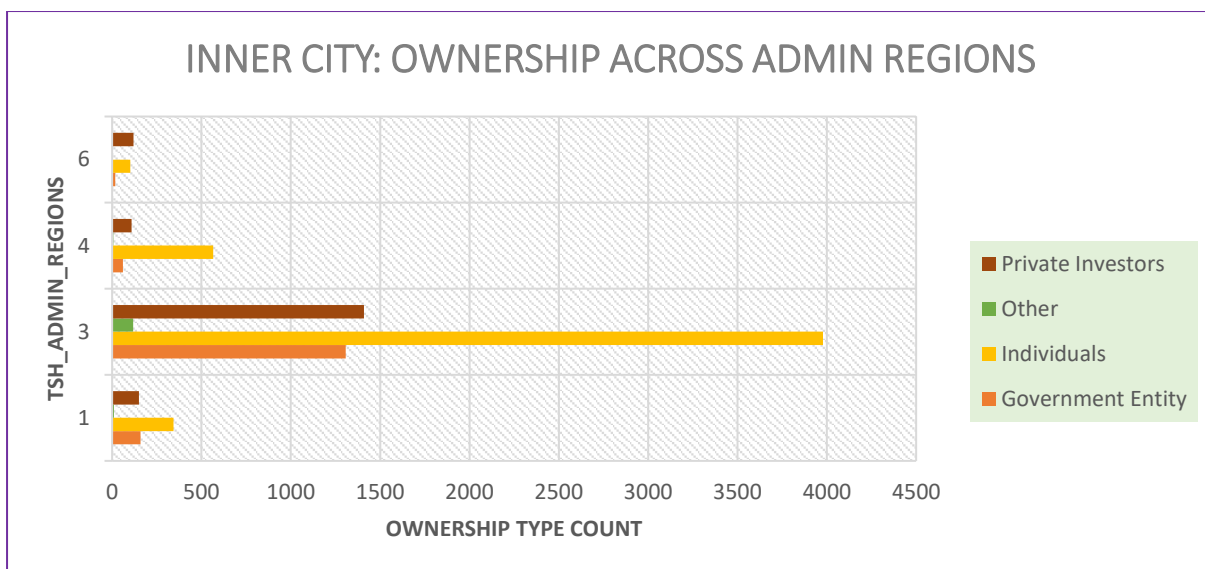

Figure 17: Inner-city Ownership Spatial Distribution per Admin Region
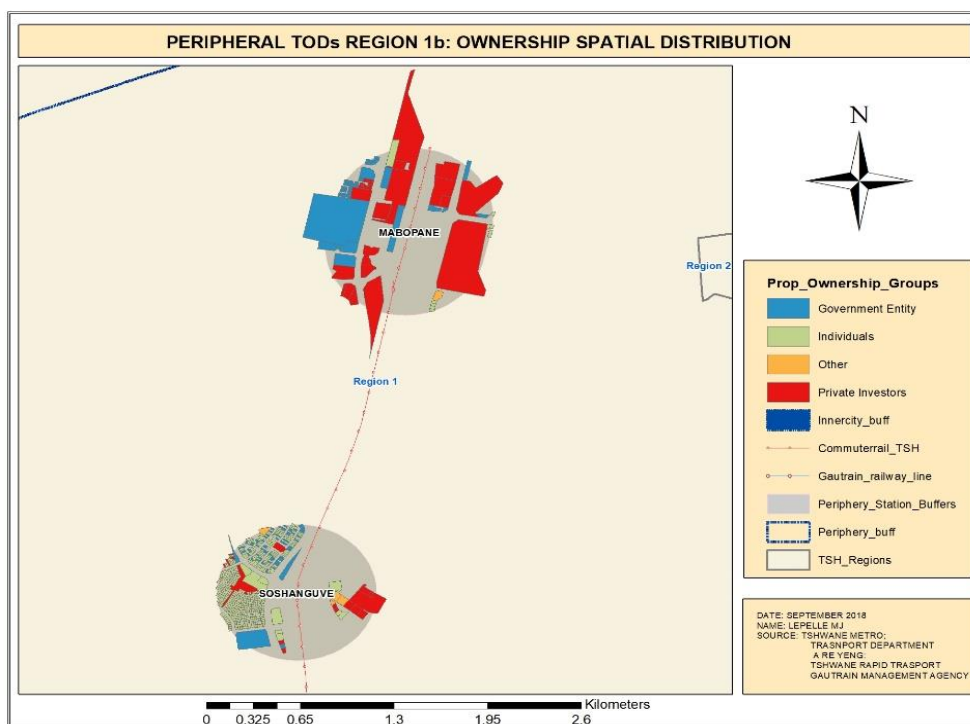

4.2.3.1   Region 1 Ownership Spatial Distribution

Region 1 ownership in the peripheral precincts illustrates an expected pattern of dominance of individual ownership due mainly to the region being residential, which is explained by the high count of individual owners. Government entity ownership is second, which is critical as it relates to the possibility to shape TOD precincts in the periphery where the state already owns the property. Private investors are third with a good count in the region, showing that some precincts are located in highly valued areas with a high likelihood for profit-making from the property sale. In the inner city of the region, individual ownership also shows prominence again

due to the location of the precincts. In these precincts, however, private ownership and government share second place in terms of representation. The precincts that make up inner-city region 1 are characterised by industrial and municipal properties (see land uses above), which explains the ownership representation of government and private investors being equal as municipal and industrial properties tend to mainly be owned by the government and private investors. Growth potential through new development in the inner city is much lower but looks more likely in the peripheral precincts of region 1.

Spatially, the ownership distribution in region 1 peripheral areas illustrates a concentration of private investor ownership in the more centrally located properties within the precincts. This allows the owners to benefit from the evolution of the precinct from residential into commercial nodes. In the inner city, the clustering of properties seems to be randomly dispersed across the precincts.

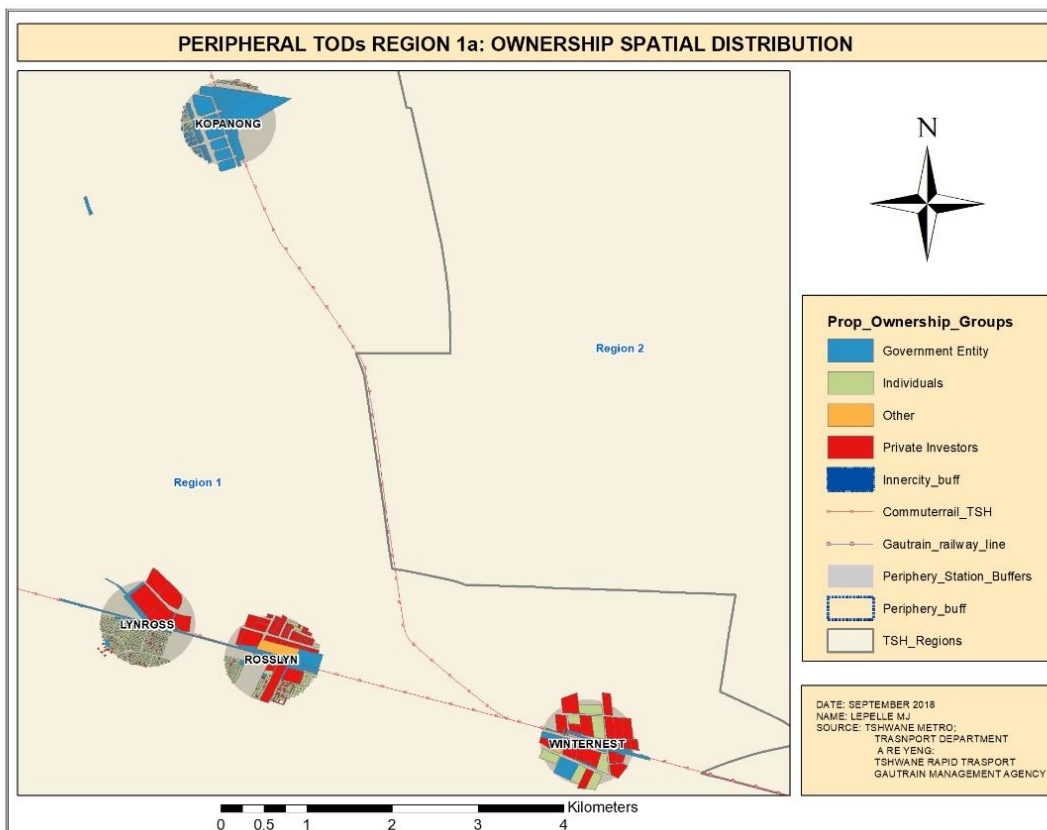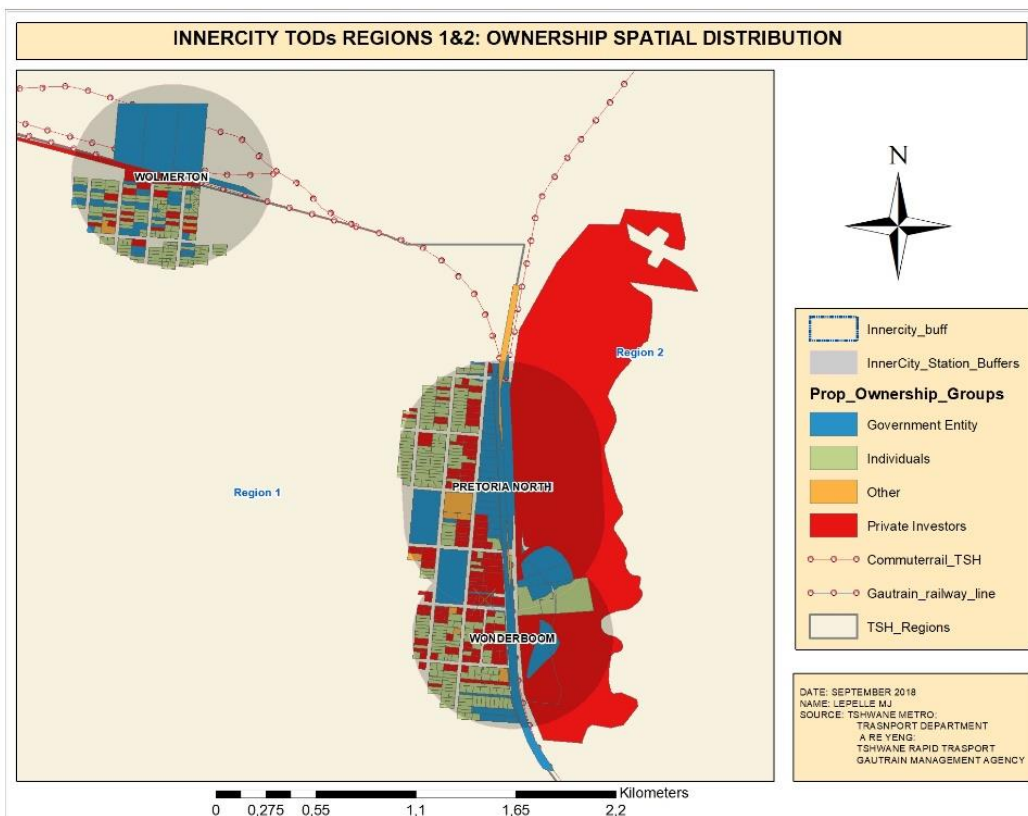*Figure 18: Peripheral Region 1 Ownership Distribution Maps*

Figure 19: Inner-city Region 1 Ownership Distribution

4.2.3.2   Region 3 Ownership Spatial Distribution

Region 3 of peripheral precincts ownership is distributed such that private investors are almost non-existent; the state owns most of the properties after individuals. In the inner city in the region, three private investors owning residential properties come after an individual, but government ownership is equally prominent. The spatial distribution of the ownership across region 3 precincts points to a more coordinated acquisition that relates to land value, as the inner-city region 3 areas see more representation of ownership by private investors while the peripheral areas enjoy next to nothing in as far as private investment.

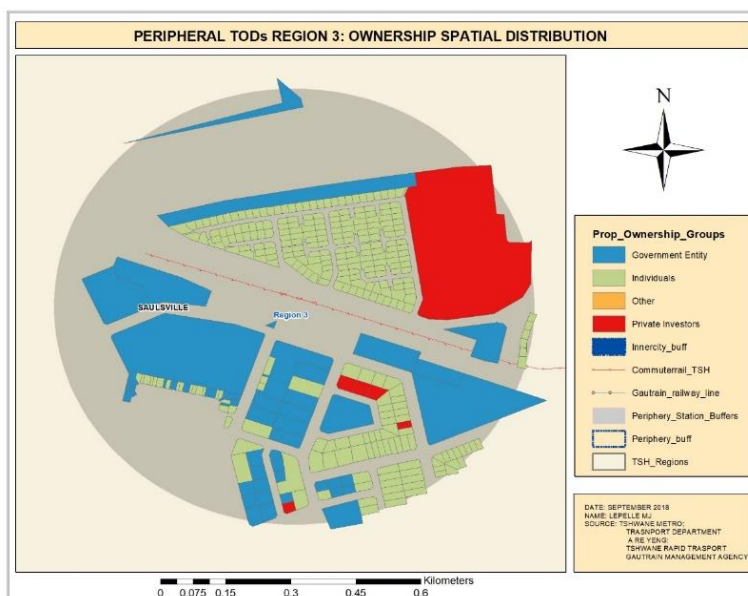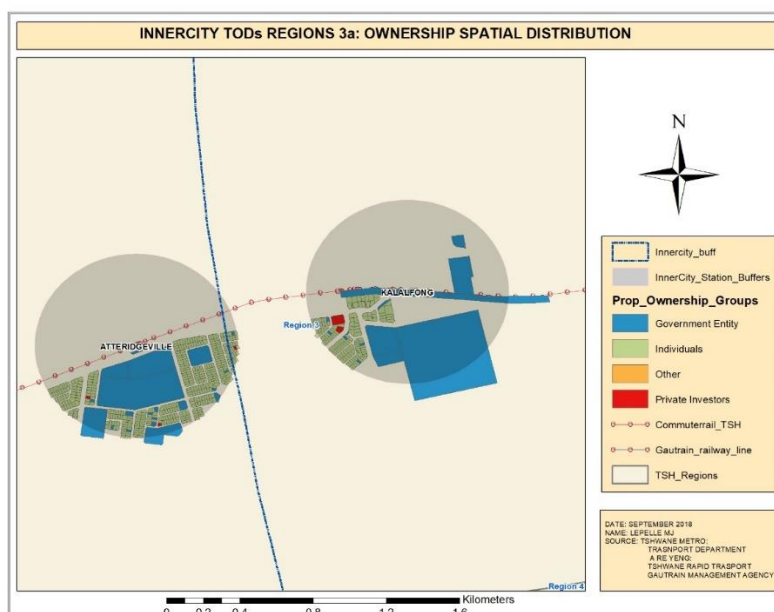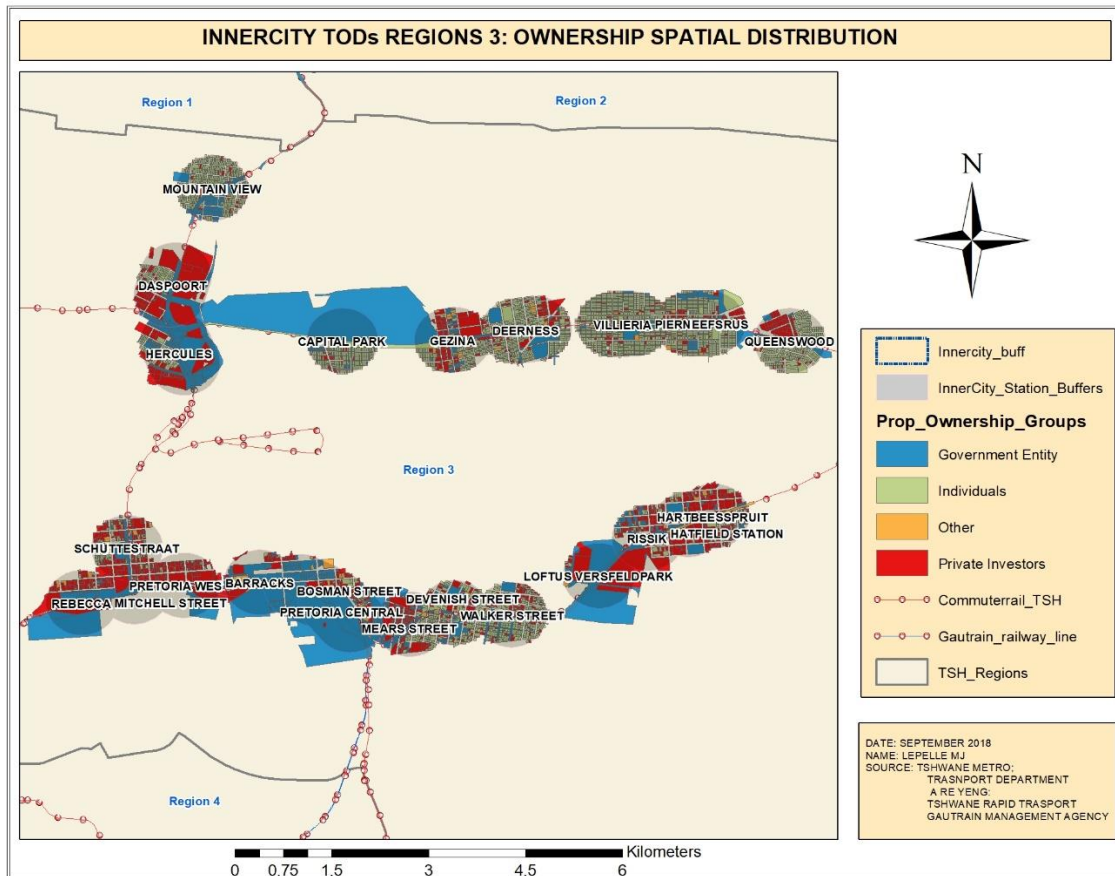*Figure 20: Peripheral Region 3 Ownership Distribution*

Figure 21: Inner-city Region 3 Ownership Distribution

4.2.3.3   Region 4 Ownership Spatial Distribution

Region 4 peripheral precincts ownership distribution shows a trend that relates to the value of the area, as private investment is uncharacteristically higher in the periphery of region 4. This, however, allows us to deduce that the Irene and Centurion areas are highly valued areas because, although in the periphery, they have high numbers of private investment in property. Inner-city region 4 sees a good representation of private investment in ownership of properties in the Lyttelton and Centurion area, which mostly have a good representation of land uses (as seen above). The state-owned areas are prominent in the inner city region 4 precincts with municipal and state properties land uses; there are some of those owned by a government entity in the precincts.

Spatial distribution – as seen below – illustrates good representation of ownership by private investors in both the peripheral and inner city of region 4 precincts. This confirms the value of the area to be high.

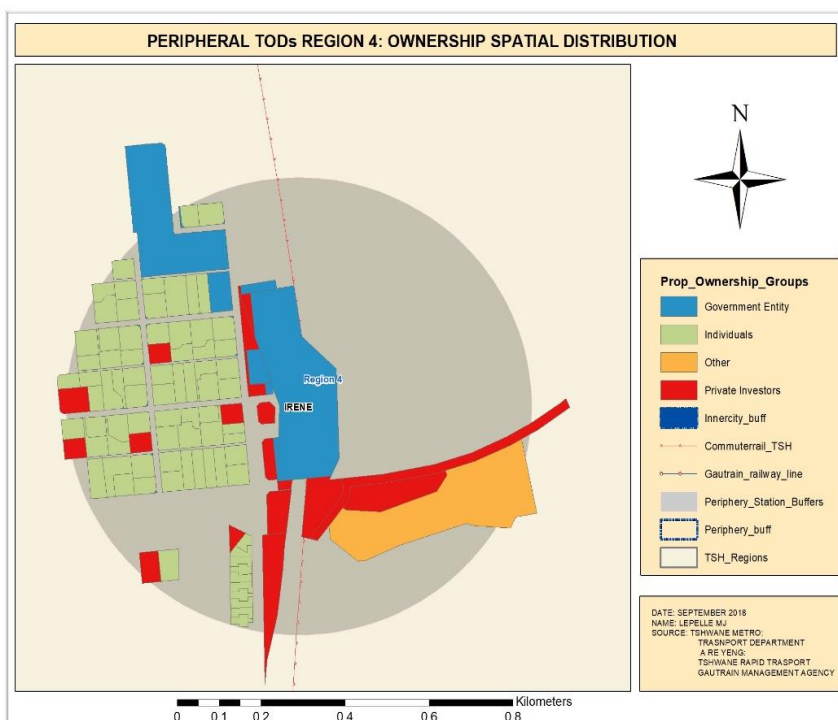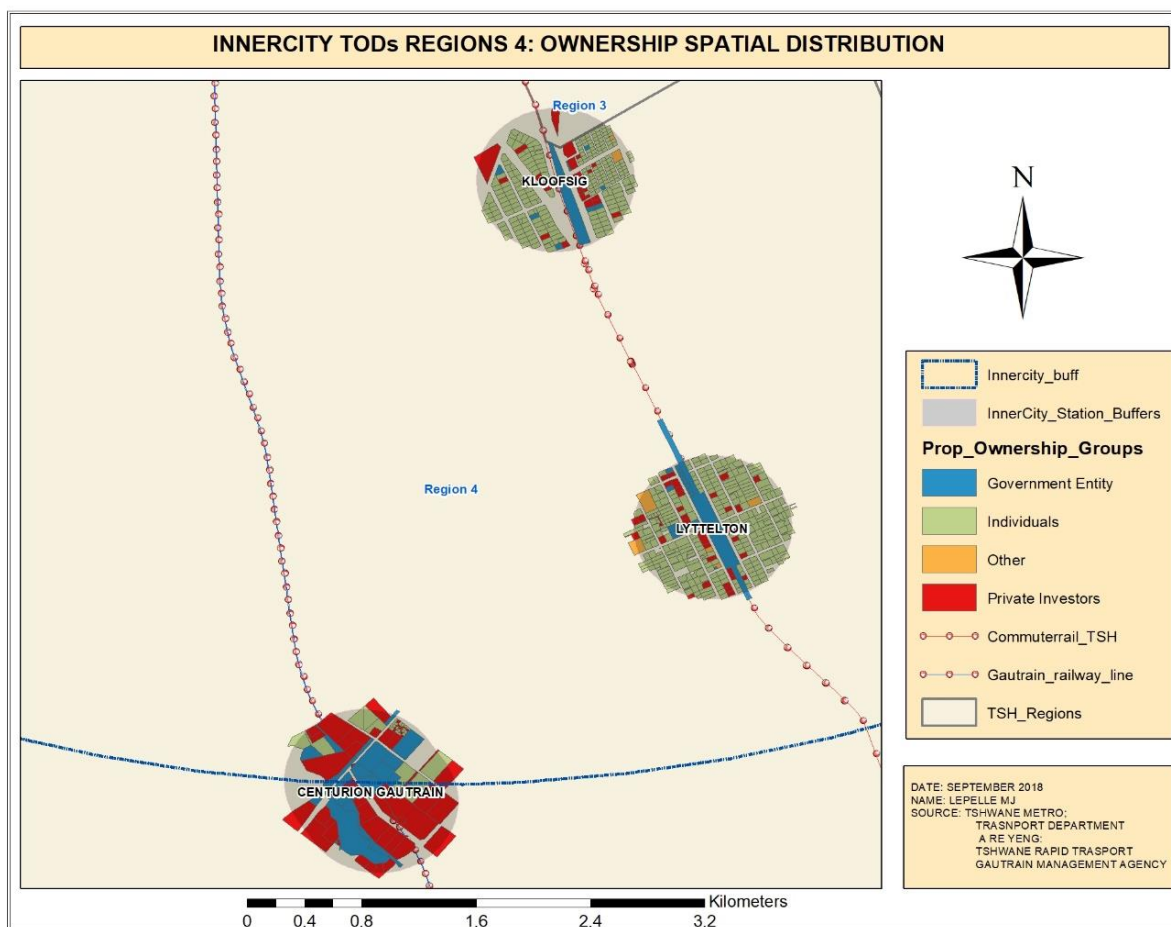*Figure 22: Peripheral Region 4 Ownership Distribution*

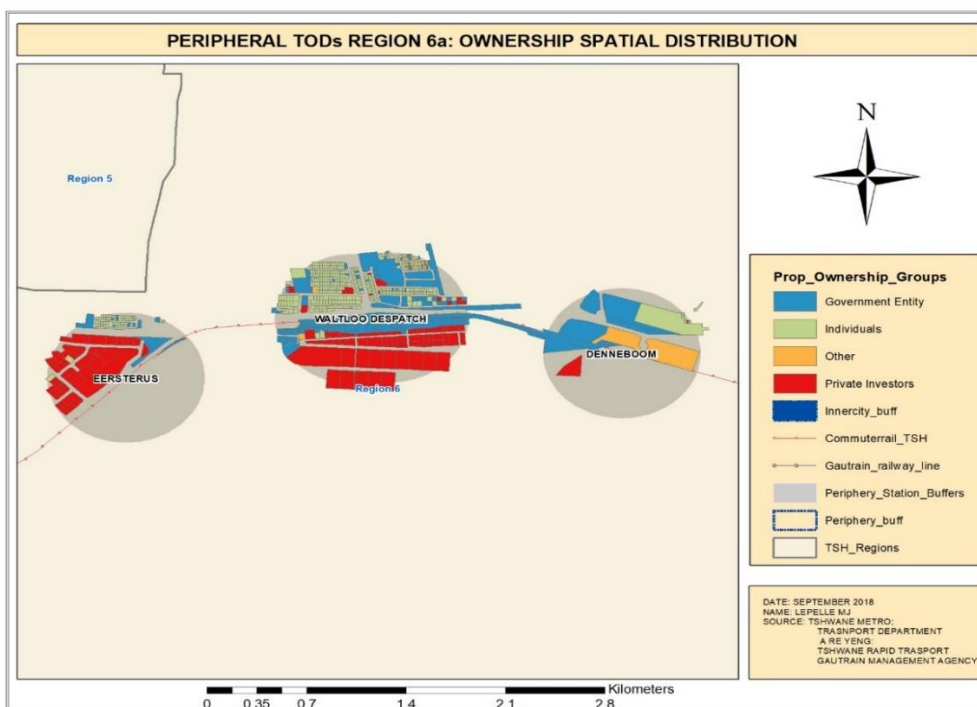*Figure 23: Inner-city Region 4 Ownership Distribution*

4.2.3.4   Region 6 Ownership Spatial Distribution

The precincts in region 6 on the peripheral areas, as expected, are dominated by individual ownership; this is due mainly to the many residential stands in the precincts in Mamelodi and surrounding areas. Private investment in property in the area is represented but is low, with the second-most owners being government entity, which is no surprise as this trend is similar to that observed in regions 1 and 3 peripheral TODs, which are low-income areas.

Inner-city region 6 ownership sees private investors dominant over individuals in the Silverton area; this area also has an industrial and commercial representation of land uses seen in region 6 land uses above. This allows the area to remain unchanged over a longer period, as private investors dictate the growth pattern and rate of development of a precinct through ownership.

Spatially, the trend of ownership in the peripheral precincts sees a better representation of private investment for precincts closer to the inner city than for those further away in the peripheral areas. Peripheral precincts private investors are prominent closer to Silverton and less pronounced for precincts in Mamelodi and in subplaces further east.

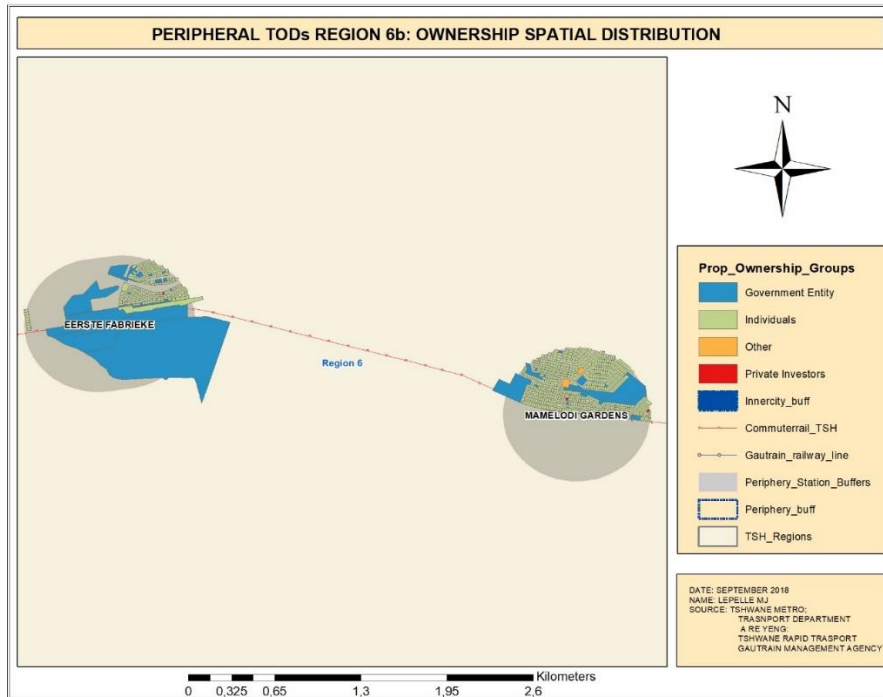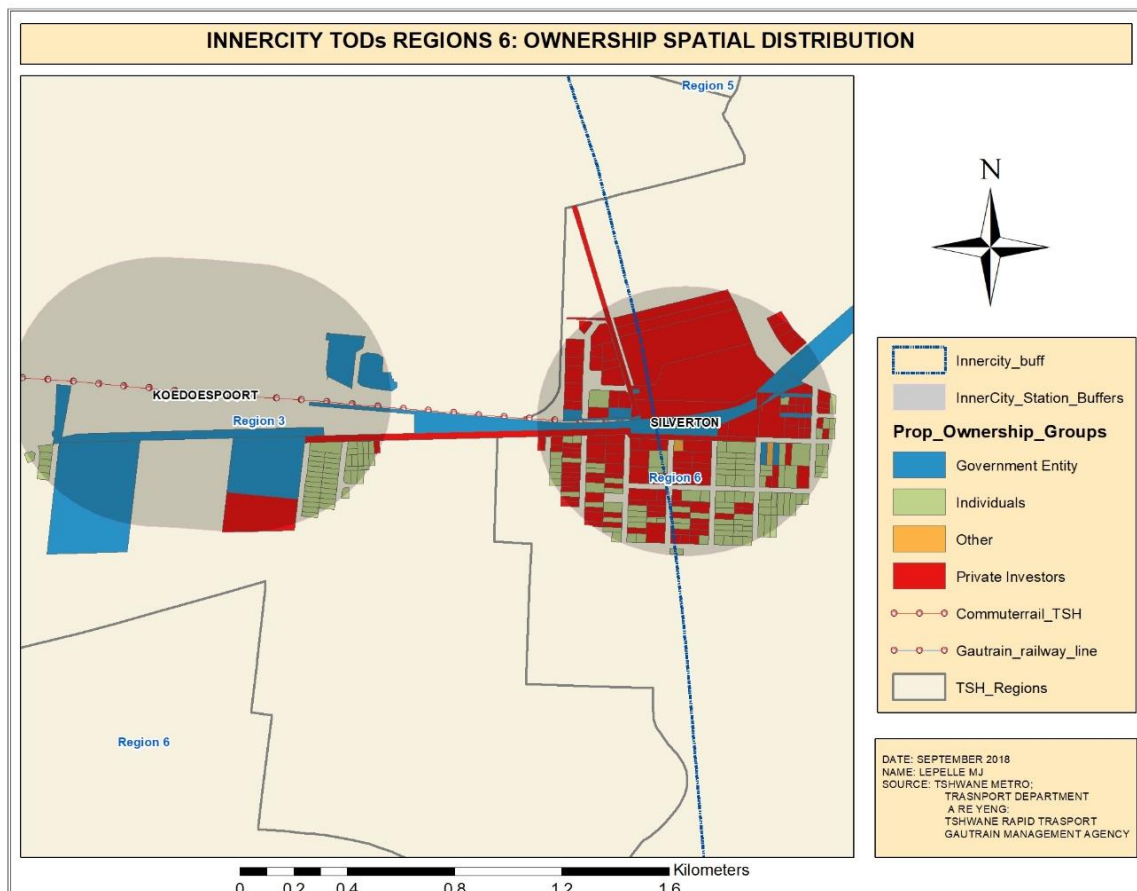*Figure 24: Peripheral Region 6 Ownership Distribution*

Figure 25: Inner-city Region 6 Ownership Distribution

4.2.4 Catchment Areas and Areas of Influence

Traditional TOD precincts are organised in an area that is compact around a transit station, allowing for the use of – amongst others – access to walking and other non-motorised transportation. It has been pointed out that the extent of a TOD precinct is largely determined by the distance that people are willing to walk to access a transport station (Crowley, et al., 2009). In developing countries like South Africa, the distance that people walk is sometimes much larger than globally accepted standard distances of 400–800 metres. This distance can reach up to 2 000 metres in the South African context and as a result, for this study, there is an inclusion of 2 000-metre buffer areas around each precinct representing the catchment areas. An analysis of the population variables for this catchment area allows for further inferences about the significance of the precinct to its surrounding areas. The analysis focuses on car ownership within the catchment area and the employment status of the population of the catchment area. These variables relate to the choice of mode of transport and affordability as has been mentioned before, as well as options available to residents of subplaces within 2 000 metres of the precincts' parameter and their characteristics.

Figure 26: Peripheral Precinct and 2 000-metre Catchment Areas
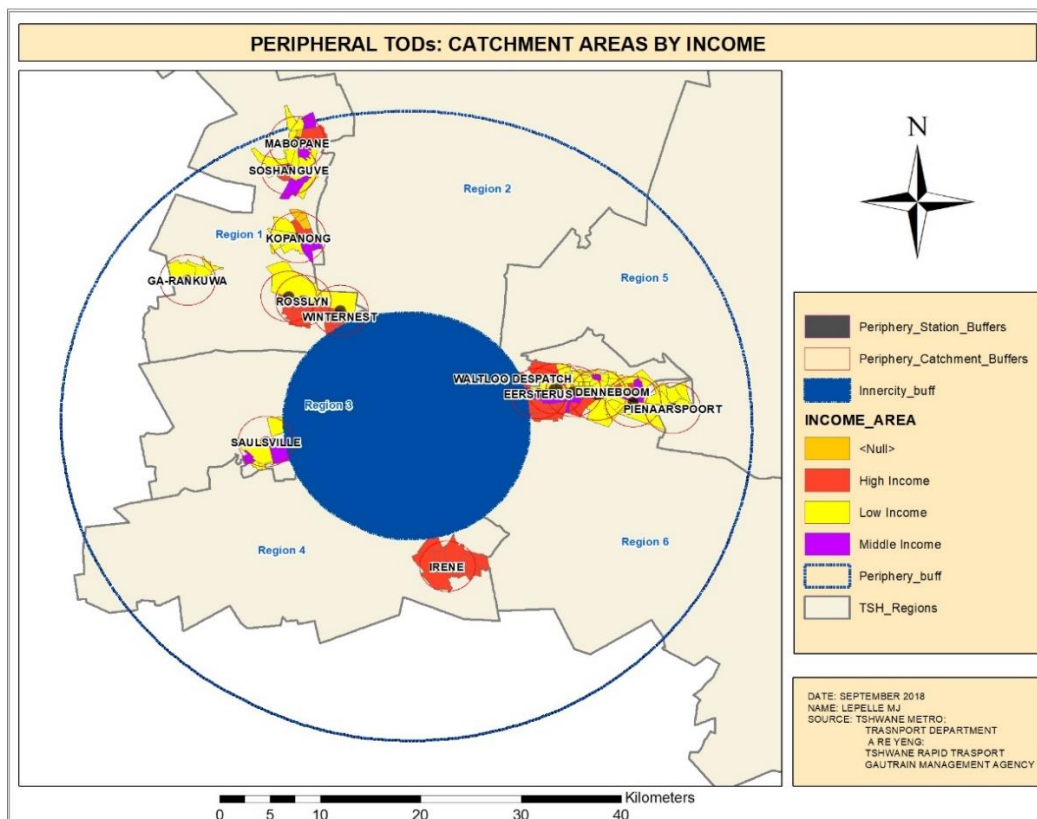
Peripheral catchment areas distribution, as seen in Figure 26 above, reaffirms the idea that regions 1, 3 and 6 of peripheral precincts are surrounded by low-income areas further away from the inner city, with some outliers in terms of high-income subplaces visible in some areas in region 1 peripheral in Mabopane and Soshanguve precincts. Lynross, Winternest and Rosslyn in region 1, along with Waltloo-Despatch in region 6 and Irene in region 4, seem to be peripheral precincts surrounded by high-income catchment areas. These areas with high levels of car ownership and employment, as seen in Figure 27 below, mean that residents in these areas mainly explore their options, utilise private cars and can afford other modes of transport, making these precincts less significant for the catchment communities, except a transport option for their workers residing in peripheral townships.

The low-income peripheral precincts catchment areas in these regions have high numbers of households without cars, as well as higher unemployment as seen in Figure 28. People access these precincts through walking to reach other parts of the city using the train; these precincts are also nodes for people to access informal services and purchase goods and services within walkable distances from their homes. Inner-city catchment areas equally reaffirm the income distribution similar to that in the precincts themselves. Figure 29 illustrates this point with the red-shaded subplaces around the precincts.
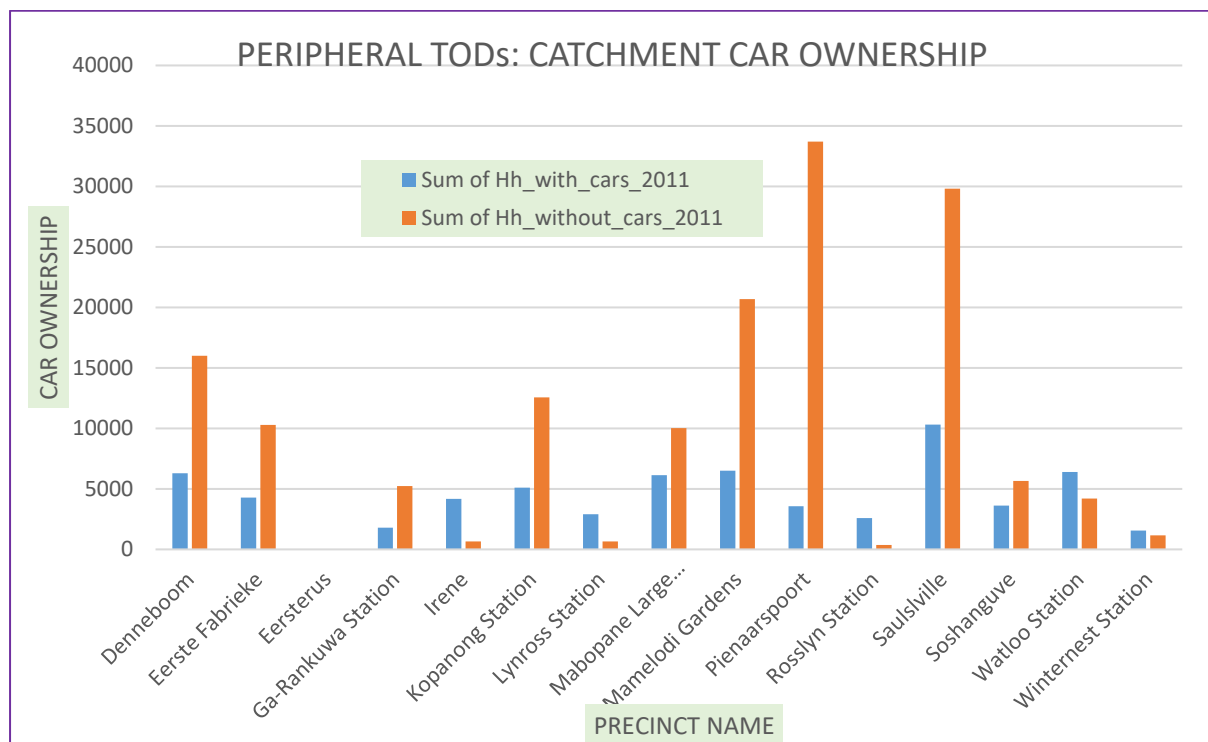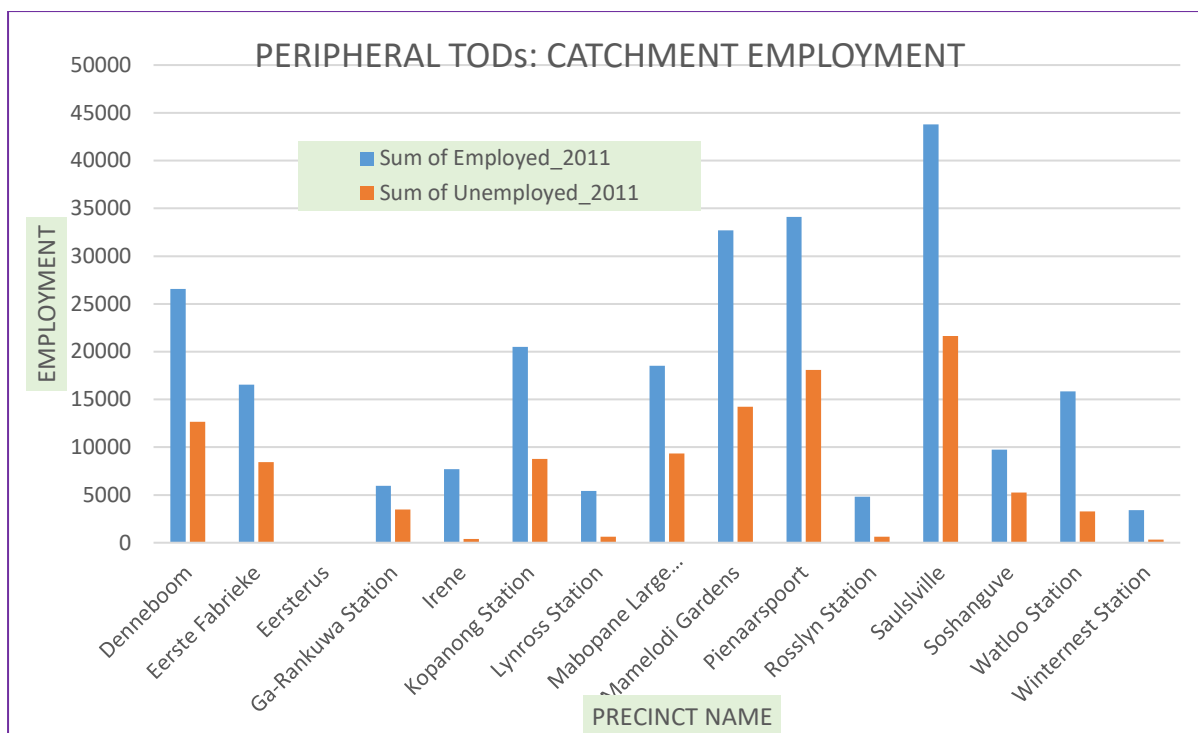
Figure 27: Peripheral Catchments Car Ownership

Figure 28: Peripheral Catchment Employment

In the inner-city precincts, due to the proximity to each station, the catchment areas like the station buffers themselves overlap, providing options for residents to access a precinct they like. As can be seen in Figure 29 below, the majority of precincts are surrounded by high-income areas with high levels of car ownership and employment. These inner-city precincts – as will be seen on trunk and feeders below – have multiple options for transportation, which means those who work in other parts of the inner city access their work areas through multiple available alternatives from within the precincts. The results of car ownership for the inner city, unlike with the peripheral precincts (as seen in Figure 30 below), confirm middle-income areas of Atteridgeville, Hatfield, Pretoria Central and Sunnyside to be the areas with households without cars being higher than those with cars. This is no problem, however, as there are plenty of public transport options for the inner city. Walking is also an option for people in region 3 precincts because of the proximity in the inner city characterised by multiple high-rise buildings and different land uses.

The employment figures in Figure 31 also identify the same catchment areas to be those with a slightly higher unemployment ratio than the other inner-city precincts. This leaves residents of precincts in this catchment area more likely to use the train and other public transport, including non-motorised options, more but also interact with the entire precinct regularly for access to cheaper goods often sold by vendors in these precincts.

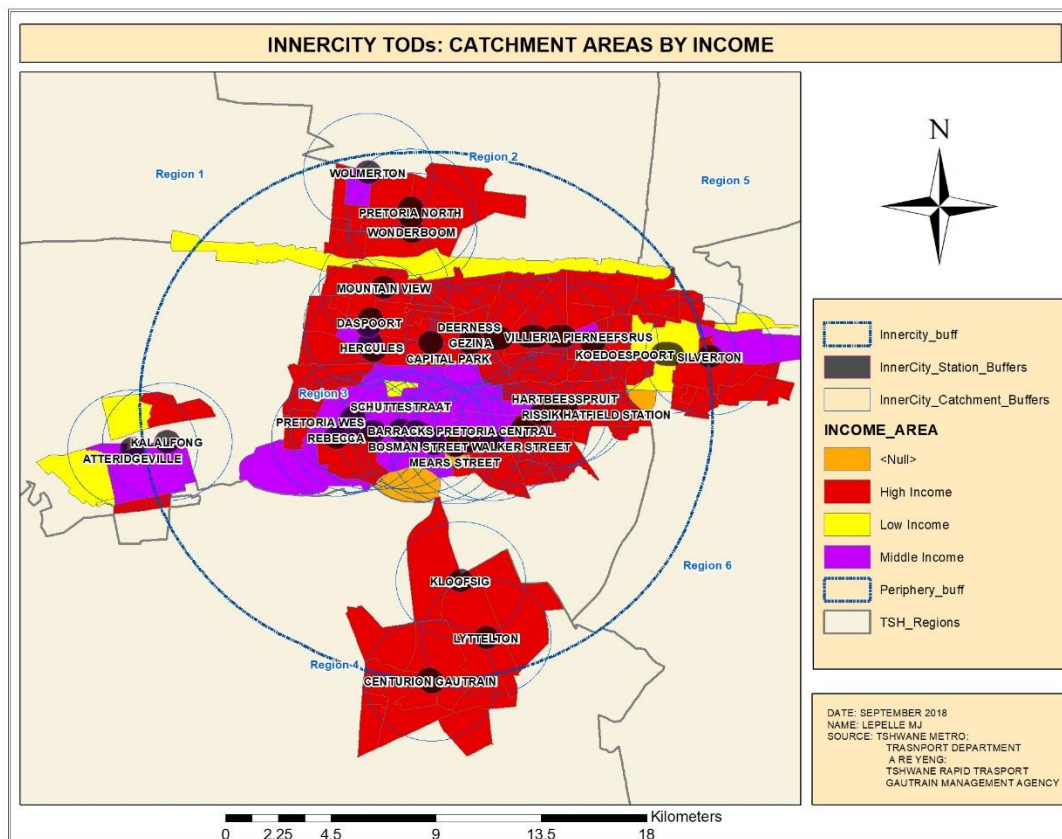*Figure 29: Inner-city Precincts and 2 000-metre Catchment areas*

Figure 30: Inner-City Catchment Car Ownership
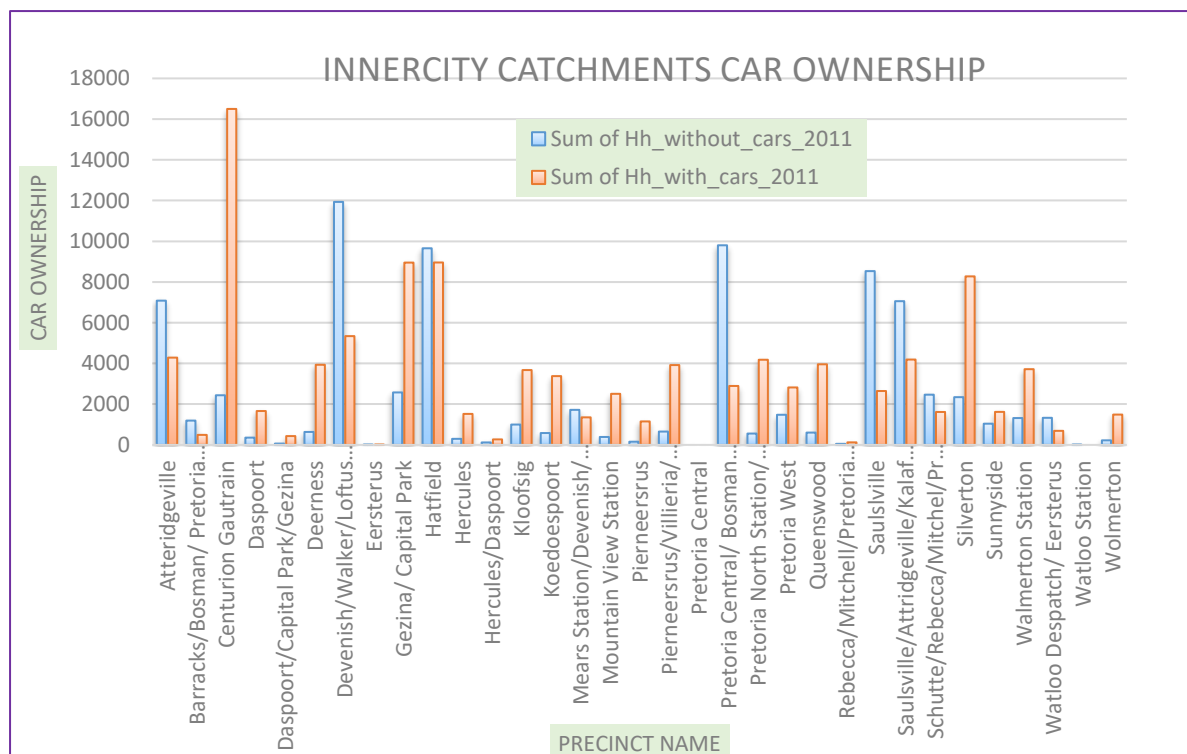
Figure 31: Inner-City Catchment Employment
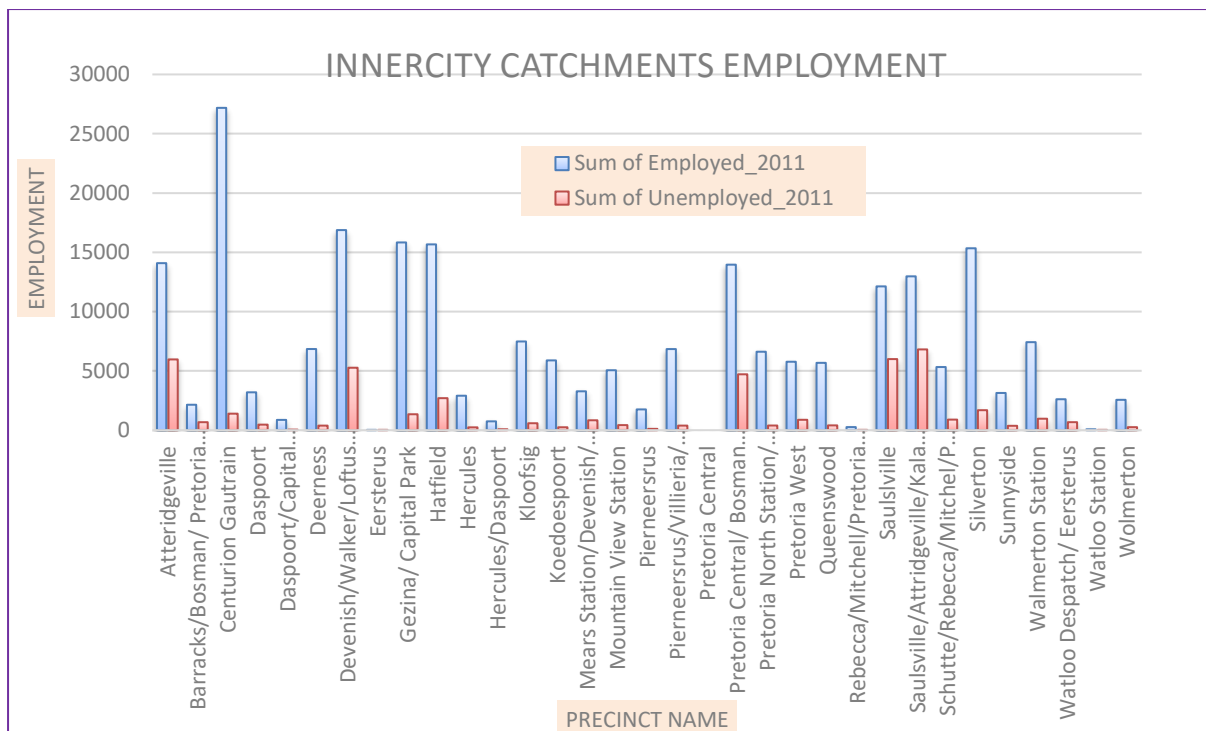
4.2.5 Trunk and Feeder Systems and Transport Relationships

The distribution of the trunk and feeder transport systems across the precincts in the City of Tshwane is skewed heavily in favour of precincts closer to and around the city centre, at the expense of those people who need adequate, affordable and reliable transportation in the peripheral areas. A look at the distribution and available options in the peripheral precincts reveals that the peripheral precincts have three main transport options that serve as both trunk and feeder systems. The taxi associations provide a service from peripheral precincts and precincts catchment areas to several inner-city destinations, and to the city centre as a trunk service. This mode is mainly accessible to most peripheral residents at a cost, which is sometimes too high. This is because most neighbourhoods are in low-income subplaces.

The second option in the peripheral precincts and catchment areas is private bus providers; as trunk systems, they depart from different areas of the periphery of the city to different destinations in the inner city (see Table 8 below). The third and final option is the Metrorail system around which the TOD precincts are centred. Access to this mode is often difficult due to the sprawl type of development, which forces people outside the catchment areas to take multiple means of transport to arrive at the rail station, depending on distances.

This sprawl spatial form of development in the low-income peripheral areas is the lifeblood of the taxi industry that also provides feeder options, mainly for subplaces outside the catchment area of the precincts. In this regard, the taxi industry has both a complementary and competitive relationship with the rail transport network in the peripheral precincts. The private buses are often deemed more reliable than the train and so, although they have routes that intersect the precincts, these buses have a competitive relationship with the train and taxi systems in the peripheral precincts.

The inner-city precincts and their catchment, in contrast to the peripheral areas, have a more integrated transport network of trunk and feeder systems. In the inner city of Tshwane, the main transport trunk systems include the Metrorail, which is a fixed-line trunk system, and the Gautrain speed rail system. The A Re Yeng BRT system in Tshwane is operational in the inner city, connecting region 1 (Pretoria North, Wonderboom) precincts with the CBD and through to Hatfield on the east edge of region 3 with a road-based trunk system with dedicated bus lanes.

The taxi associations provide integral trunk services in the city whilst also serving as a feeder system for the other three trunk facilities due to its reach, and close the gaps left by the bus routes. The Tshwane Bus Service buses serve as a trunk and feeder system, as they have routes throughout the inner city. Other modes like metred taxis and Uber are operational in the inner-city precincts. Overlaps in routes between the Tshwane Bus Service and Tshwane Rapid Transit (TRT) mean the modes are complementary, while competing for users in other instances. The TRT also has its own feeder and complementary routes as seen in Figure 33 below. The Gaubus system feeds the Gautrain, while taxis, metred taxis, Uber and private buses in some instances provide a feeder option for the three fixed trunk options in the inner city.

Figure 33 uses a thematic map to highlight the different feeders and trunks while Table 7 illustrates the available feeder transport options in the inner city. Table 8 shows the list of operators and the direction and destination of feeders and operating companies in the specific regions.

Figure 32: Peripheral Trunk and Feeders
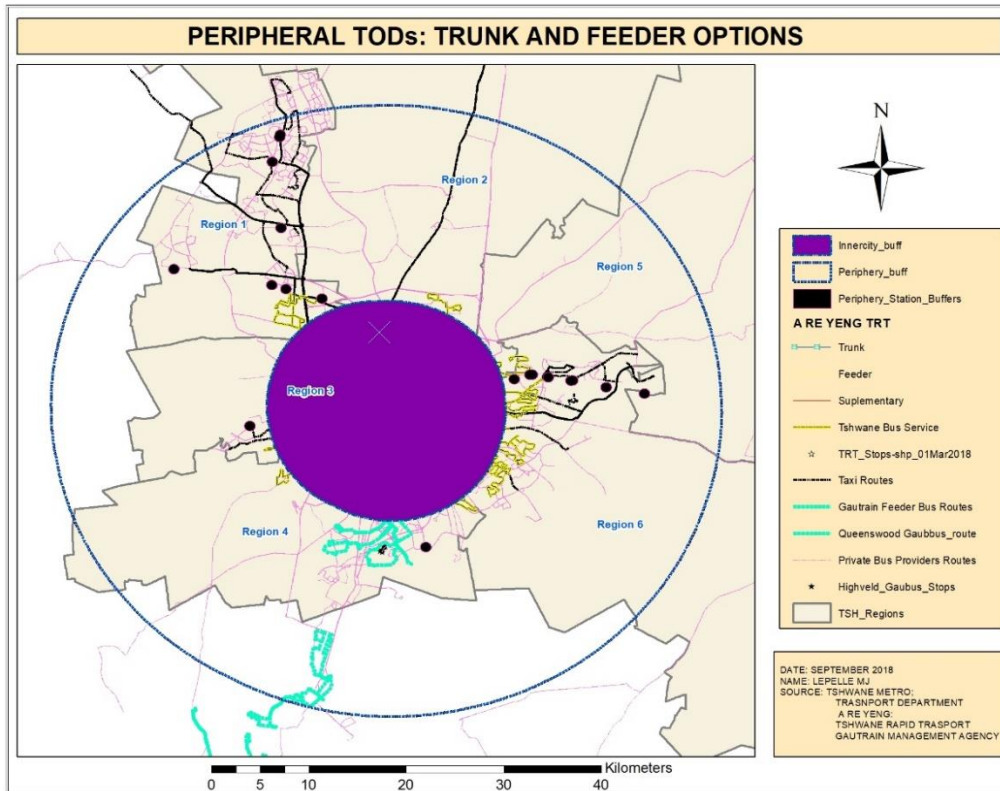
Figure 33: Inner-city Trunk and Feeders
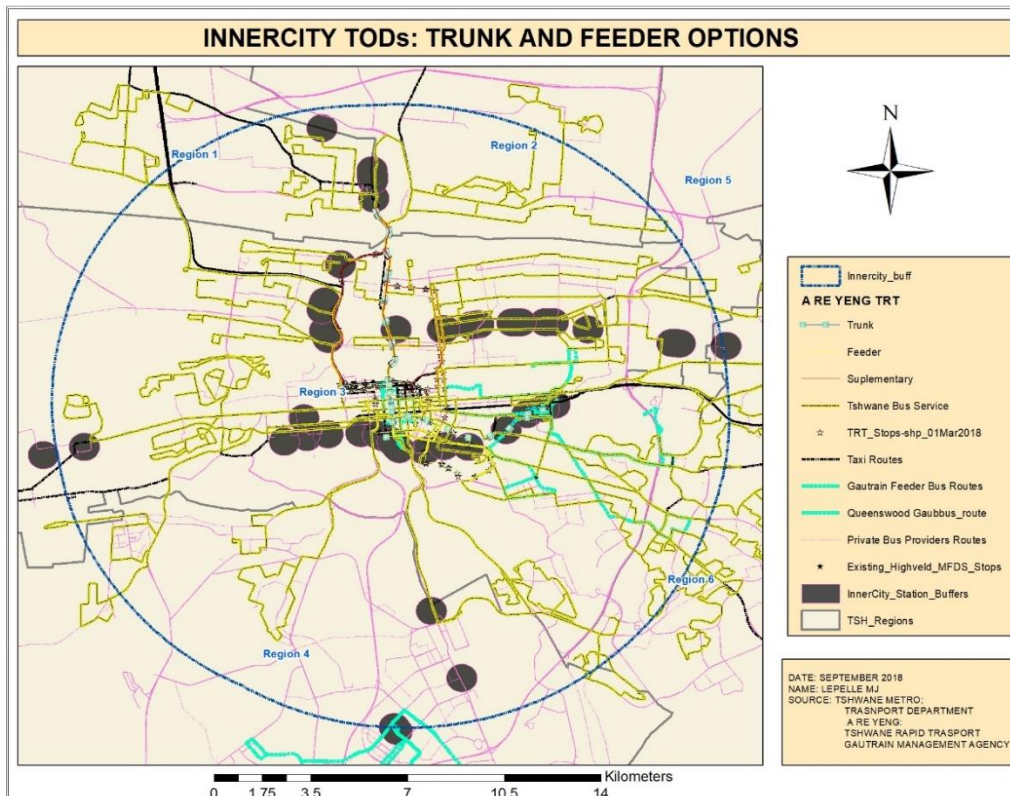
Table 7: Inner City-based Transport Feeder Options

Number	Feeder Type	Provider	Stations Available In	
1.	Taxis	Taxi associations	All inner-city stations	
2.	Metred taxi	Metred taxi associations	Sunnyside, Hatfield, Pretoria Central, Centurion and Lyttelton	
3.	Uber	Uber providers	All inner-city precincts	
4.	Tshwane Bus Service	Metro	All inner-city precincts	
5.	Bus Rapid Transit	Metro	Wonderboom, Pretoria Central, Sunnyside and Hatfield	
6.	Gaubus	Gautrain Management Agency	Pretoria Central, Hatfield and Centurion	
7.	Walking	Individuals	All	

Table 8: City of Tshwane – Private Bus Operator Routes and Destinations

No.	Company	Route description	Originating buffer	Destination buffer	Destination precinct	Route type
1.	**A Re Yeng Mamelodi**	**Mamelodi –** Wierdapark, Centurion, Sunderland Ridge	Periphery	Periphery	None	Trunk
		Mamelodi – Hazelwood, Moreletapark, CSIR, Erasmusrand, Faerie Glen, Constantia Park, Garsfontein, Menlyn, Murrayfield, Waterkloof, Monument Park, Silver Lakes	Periphery	Inner city and periphery	Eerste fabrieke, Denneboom and Waltloo	Trunk and feeder
		Mamelodi – Wonderboom, Rosslyn, Sinoville	Periphery	Periphery and inner city	Wonderboom	Trunk and feeder
		Mamelodi – Callies, PTA Academic Hospital, Eastlynne, Mayville, Waltloo	Periphery	Inner city	Watloo	Trunk and feeder
2.	**Atteridgeville Bus Service (ABS)**	**Atteridgeville –** Callies, Saulsville, CBD	Periphery	Periphery	Saulsville	Feeder
		Atteridgeville – Rosslyn, Ga-Rankuwa, Mahem, Wonderboom, Wonderpark, PTA West Hop	Periphery	Periphery and inner city	Wonderboom, Ga-Rankuwa and Rosslyn	Trunk
		Atteridgeville – Wierdapark, Menlyn, Waterkloof, Valhalla, Centurion, Faerie Glen, Moreletapark, Lynnwood, Wierdapark, The Reeds, Swartkop (Tek Base), Erasmia, Moreletapark, ISCOR, Sunderland Ridge, Voortrekkerhoogte	Periphery	Inner city	None	Trunk
3.	**Putco Soshanguve and Mpumalanga**	**Soshanguve –** The Reeds, Centurion, Roodeplaat, Rosslyn, Irene, Central city, Denneboom Station, Baviaanspoort, Queenswood	Periphery	Periphery and inner city	Mabopane, Denneboom	Trunk and feeder
		Moloto Gate/Big Tree – Hatfield, Centurion, Denneboom Station, Doornkloof, Faerie Glen, Mahem, Hazelwood, Eastlynne, Eersterus, Orchards, Rosslyn, Menlo Park, Moreletapark, Silver Lakes, Wonderboom,	Outside periphery	Periphery and inner city	Hatfield, Centurion, Wonderboom and Denneboom	Trunk and feeder

		Hornsnek Road, Wapadrand, Callies				
10.	**NWS Botlhaba Tswana Depot**	**Makapanstad/ Hammanskraal –** Moreletapark, Rosslyn, Baviaanspoort, Bosplaas West, Centurion, Mamelodi, PTA Station, Derdepoort, De Putten, Wierda Glen, Doringkloof, Midstream, Voortrekkerhoogte, Tek Base, Elarduspark, Waterkloof Air Base, Pierre van Ryneveld, Woodlands, Erasmusrand, Groenkloof, Garsfontein	Outside periphery	Periphery and inner city	None	Trunk
11.	**NWS Batswana Gare Depot**	**Ga Rankuwa –** Rosslyn, Centurion, Wonderpark, Capital Park, Erasmus, The Reeds, Irene, ISCOR, Kollonade, Willows, Waverly, Laudium, Sunderland Ridge, Callies, Pretoria Station, Mamelodi, Doornpoort, Elarduspark, Groenkloof, Pierre van Ryneveld, Eersterus, Silver Lakes, Waterkloof Air Base, Constantia Park, Watloo, Capital Park	Periphery	Periphery and inner city	Mabopane, Irene, Watloo, Capital Park and Denneboom	Trunk and feeder
12	**Thari Bus Service (near Brits)**	**Ga Rankuwa –** Centurion, Mamelodi, Wonderpark, Valhalla, Rosslyn, Sunderland Ridge, Waterkloof, Vaalboschsloot, Willows, CSIR, Gezina, PTA CBD	Periphery	Inner city and periphery	None	Trunk

5   Analysis Results

The analysis of car ownership and employment statistics within peripheral precincts confirmed that most households are in fact low-income neighbourhoods with high unemployment and without cars, and it can thus be inferred that they depend on available public transport for their commutes. In the inner city, the majority of the precincts are located in high-income neighbourhoods characterised by high levels of employed individuals with the highest representation of households with cars. This negatively affects the use of public transport in the inner-city precincts as people retain multiple transport options, including private cars, which explains the TOD strategy set out to discourage the use of private cars by providing an abundance of public transport options for inner-city precincts.

The trunk and feeder options further confirm the distribution of public transport options to be in favour of inner-city precincts and to follow a pattern that suggests that transport accessibility is easier for inner-city precinct neighbourhoods. The study confirms this to be different in the peripheral precincts, as limited available public transport seems to be the order of the day as illustrated by the availability of only taxi (paratransit) and private bus operators as the road-based public transport options in the peripheral precincts. The relationship for the two available road-based public transport options in the peripheral precincts and the train is thus a competitive more than a complementary one. It is confirmed that inner-city precincts have multiple trunk and feeder options, that the relations between the different modes are both complementary and competitive, while due to their spatial proximity and overlapping nature of the precincts, walking as a non-motorised option is useful for the catchment areas of the precincts. The analysis showed that peripheral precincts catchment areas, with a limitation in road infrastructure investment, require the use of different modes to access the precincts, which at times serve as feeder systems for the trains while in other instances competing with the trains.

The analysis of the precincts' land uses, ownership spatial distribution, and representation to confirm type and form of precincts were divided into administrative regions. It confirmed that in region 1 peripheral precincts, business and commercial, agricultural, industrial and municipal properties cluster at the centre of the precincts while most of the residential properties are located on the outer edge of the precincts. The ownership also affirms that most of those centrally based peripheral properties are owned by an entity of the state in low-income precincts subplaces, while individuals mainly own the residential properties. This pattern of ownership and land-use distribution is key for supporting and encouraging TOD strategies in

region 1 peripheral areas. In inner city region 1, by contrast, the analysis affirms a distribution of land use showing clusters of agricultural, business and commercial, industrial and municipal land uses spread out across the precincts, mixing with residential and other land uses. As such, this high land-use mix affirms a more traditional TOD feel. Land ownership affirms dominance by private investors, which confirms the high value of the area encouraging investment in property. This dominance by private investors with regard to ownership, coupled with the lack of available vacant land, means the potential to encourage and support TOD strategies in these precincts will be negatively impacted as private investors decide when or not to sell their properties.

Regions 3 and 6 results of the analysis are quite similar to those in region 1 in terms of the distributional pattern of land uses in the peripheral precincts. In these regions, agricultural, business and commercial, industrial and municipal properties equally cluster centrally and residential properties are located in the outer edges of the precincts; government dominates land ownership over private investors. Although this study could not answer why this land-use distributional pattern is as it is, it confirmed what this precinct represents, which is economic nodes for their service areas with a concentration of economic land uses clustering centrally serving as a form of CBD. The inner-city precincts in regions 3 and 6 by contrast, with their multiple land use and land ownership dominated by private investors, enjoy an abundance of public transport options and, as indicated by the overlapping of the precincts across a smaller area, spatially represent the closest characteristics of traditional TODs as defined earlier in the study.

Region 4 analysis results confirm that both the peripheral and inner city of this region is characterised by high household income. Property distribution is such that the peripheral precinct land uses are dominated mainly by residential properties and minimal land-use mix, whilst in the inner city there is a lot more business and commercial properties with a better mix of land uses, a pattern that highlighted the value of land and high income to be more important than the spatial distance. This is further confirmed by the fact that ownership distribution across region 4 sees both peripheral and inner-city precincts have high private investor owners. The difference between them is that peripheral precincts enjoy available vacant land, which is not there in the inner-city precincts; this means there are some prospects of implementing future TOD strategies in region 4 peripheral precincts despite the area having large numbers of private investor ownership.

6   Conclusions and Recommendation

This study set out to compare TOD precincts in peripheral and inner-city areas of the City of Tshwane with a focus on spatial relationships. The results of the study confirm the hypothesis and answer the study questions. The study is based on 15 peripheral and 33 inner-city precincts covering 4 administrative regions in Tshwane. This study has thus critically answered what the current land-use spatial distributional patterns in the City of Tshwane look like. It was able to display the pattern of employment, income and car and property ownership across the precincts in the city, and confirm through inference derived from spatial proximities the relationship between paratransit in the form of taxis with the other modes of road- and rail-based transport in both inner-city and peripheral precincts. It was noted (Higgins & Kanaroglou, 2017) that several factors affect the development of TODs; this study highlighted land ownership which is one of those factors, but also that the socio-economic characteristics of the communities in Tshwane seem to be key in shaping the precincts. This may relate to the history of the country because of how distinctive the peripheral and inner-city precincts are and what they seem to represent. However, it is a fact that the spatial distribution of the types of properties could also have been shaped by years of zoning plans of the City of Tshwane.

Taking into account what some of the literature points out on TODs, it is clear that peripheral TODs in Tshwane can be categorised as suburban TODs as they have strong developmental potential, and they may act as a hub for surrounding suburbs and should provide a range of shops. Others like Mabopane and Denneboom are activity centres, which provide a comprehensive range of retail, commercial, services, community services and facilities and other employment opportunities. In the inner city, the middle-income precincts are classified as city centre as they have excellent transit connections and established high-density and mixed-use built form, and the high-income precincts are classified as urban supported by frequent transit services and well connected to employment hubs and key destinations. The potential willingness of people to walk to access TOD stations in the peripheral areas means that the geographic extent of TOD precincts there reaches the end of the catchment areas, making those precincts up to 2 000 metres from the station. Questions on ridership will only fully be answered when ridership for the rail, bus and taxi figures are provided, which leaves a more detailed option for future studies open.

The study recommends that, in order for regional spatial development frameworks (RSDFs) and TOD strategies to be effectively implemented in the peripheral areas of the city, property

ownership within precincts have to be a major factor that is considered during the planning phase. Public transport provision in the peripheral precincts has to be improved through the integration of road-based public transport and paratransit elements. Peripheral precincts located in low-income areas should be supported to develop as nodes through the encouragement of investment by private parties, thereby creating employment opportunities, and government making available their land and properties in those precincts.

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