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Restructuring Gauteng City Region in South Africa: Is a Transportation Solution the Answer?

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Abstract

The Gauteng city region forms the economic hub of socio-economic development and growth in South Africa. The province itself includes the Johannesburg metropolitan city, Ekurhuleni metropolitan city as well as Tshwane municipality—key urban growth regions of Gauteng province, South Africa, and by extension Southern Africa. The region exhibits the rapid urbanisation challenges typical in any developing country city. Rural–urban migration, pressure on infrastructure demand, supply and capacity constraints and mismatches in urban governance structures with respect to service delivery have remained stubborn challenges. Initiatives and strategies to resolve urban traffic congestion such as through road construction and highway expansion (physical instrument), e-tolling of roads (financial instrument), innovative housing and waste management technology deployment (technology instruments) as well as presenting advanced spatial planning and development and management systems (planning and regulatory instruments) have been employed with mixed fortunes in attempts to (re)solve the urban problems in the study area. Making use of a thematic approach and technique, the major urbanisation issues are explored and solutions proffered. Recommendations revolve around the need to implement robust and progressive rafts of projects, programmes, activities, measures and actions to reverse spatial fragmentation and spatially inefficient transport induced and perpetuated disadvantages.

Keywords: restructuring, fragmentation, city region, urbanisation, transportation, solutions

1. Introduction

Gauteng city region is defined as the economic hub of South Africa constituting Johannesburg metropolitan city, Ekurhuleni metropolitan city as well as Tshwane (formerly Pretoria) city [1–3].

This means that economic and social opportunities are spatially concentrated in the Gauteng city region, which contributes approximately 40% of the gross domestic product (GDP) for the South African economy although the geographic space occupied by the region is 2% of the total land area of South Africa [4]. Within the auspices of this current spatial structuring and subject to the processes and outcomes of successive restructuring actions and measures occurring in the Gauteng city region, various forms of spatial and transportation challenges and opportunities have emerged. As a result, the Gauteng city region is experiencing rapid urbanisation, which is a common feature for cities in the global South [4–6]. In South Africa, when one compares all the nine provinces, Gauteng attracts the largest number of migrants, with an estimated recorded net increase of 543,000 between the years 2011 and 2016 [7–10]. Given the apartheid geography and history of South Africa, Gauteng province inherited a spatially fragmented, scattered and sprawled urban set-up [11, 12]. This existing spatial structure has implications regarding long commuting times, long journey times and great distances that buses, motorists and trains travel between areas of residences with respect to areas of socio-economic opportunities [4, 7, 13–15]. This spatial formation has led to spatial inefficiency and inequity that manifests itself in terms of multiple forms of deprivation that impact on family systems, spatial disconnects, continued public transport subsidy (which is argued by others as the invisible apartheid transport tax that current generations and government has to live with) as well as a complex non-optimised governance delivery set-up and inadequate institutional and governance structure [2, 16–19].

1.1. Purpose

This chapter examines the impact of rapid rural–urban migration on the Gauteng space structure, economy and transportation landscape. This impact is critiqued with respect to the ensuring pressure on infrastructure created, the unravelling capacity constraints faced and mismatches in urban governance structures with respect to service delivery utilising a transportation and spatial planning approach and perspective. The objectives of this chapter include:

1. Exploring the concepts and notions of spatial fragmentation and restructuring modalities with respect to the Gauteng province of South Africa
2. Examining the key spatial and transportation challenges facing the Gauteng province of South Africa
3. Describing the impact of rapid urbanisation on the spatial arrangements and systems in Gauteng province making use of the transportation platform as a unit of analysis and intervention lever
4. Providing a rejoinder regarding how the spatial and transportation challenges in the region can be addressed with a view to closing the gaps regarding spatial and transport inefficiencies in the Gauteng city region of South Africa

In answering the four mentioned questions, the overarching question ‘is a transportation solution the answer’ was used to unpack and construct the departure point for the paper.

2. Research methodology

A desktop survey methodology was adopted in analysing spatial and transportation documents found at both the national, provincial and municipal level in the Gauteng city region. **Table 1** presents an overview of the secondary data sources that were accessed and analysed for spatial and transportation trends and themes used in compiling this chapter.

From **Table 1**, the researcher further made use of a gap analysis to identify and codify themes for detailed discussion. The analytical framework was informed by the application of the spatial and transportation system theory within the context of a polycentrism urban spatial growth paradigm approach. The application of the above-explained methodology was instrumental in generating vital insights and establishing patterns linked to spatial and transportation landscape in the study area with respect to whether efficiencies or lack of efficiencies exist thereof.

3. Literature review

Understanding spatial restructuring and transportation solutions for Gauteng city region requires an appreciation of the notions and concepts that constitute spatiality as well as sustainable transportation solutions. This section, therefore, reviews the key concepts and notions of spatial fragmentation, spatial restructuring, urban systems theory as well as the urban polycentricism growth and management approach. This is critical in order to provide a common understanding of how these key notions, concepts and approaches are used in this chapter.

3.1. The notion and concept of spatial fragmentation

Spatial fragmentation is defined as the physical separation, division, scattering, alienation, divorce and exclusion of urban land parcels/areas/settlements/locations/uses/activities by the use of great distance and through buffering techniques such as open spaces, roads, railway lines, etc. from complementary and critical socio-economic opportunity areas [2, 4]. Urban spatial fragmentation therefore manifests itself in terms of sprawled settlements, urban settlements in which commuters travel long distances from residential areas to industrial/commercial working areas and is associated with low-density developments that promote the use of automobiles.

3.2. The notion and concept of spatial restructuring

Spatial restructuring is the exercise aimed at changing and transforming the spatial structure of an existing urban area from a growth and development trajectory that encourages inefficiency and fragmented development to one that encourages land densification, compaction and integration of urban land parcels/areas/settlements/locations/uses/activities through infill developments, promoting high-density developments ably supported by a transit-oriented

Name	Status	Population census 1996-10-09	Population census 2001-10-09	Population census 2011-10-09	Datasets accessed	Documents accessed
Gauteng	Province	7,834,125	9,388,854	12,272,263	1. National Household Travel Survey (NHTS), 2003 and NHTS, 2013	10. National Land Transport Strategic Framework 2006–2011
City of Johannesburg	Metropolitan municipality	2,638,470	3,226,060	4,434,827	2. Household surveys and observation surveys	11. Public Transport Strategy, 2007
City of Tshwane (Pretoria)	Metropolitan municipality	1,792,360	2,142,320	2,921,488	3. Gauteng City Region Observatory datasets	12. Gauteng Spatial development Framework 2011
Ekurhuleni (East Rand)	Metropolitan municipality	2,026,980	2,481,760	3,178,470	4. Stats South Africa, 2011	13. Gauteng Land Transport Framework (2009–2014)
Emfuleni	Local Municipality	597,285	657,949	721,663	5. Integrated Transport Plan (ITP), Johannesburg (2003–2008)	14. Comprehensive Integrated Transport Plan (CITP) (City of Tshwane) 2006–2011
Lesedi	Local municipality	66,206	71,868	99,520	6. Passenger Rail Agency of South Africa (PRASA) annual reports	15. Gauteng Infrastructure Renewal and Investment Plan (2008)
Merafong city	Local municipality	209,727	210,481	197,520	7. South African National Roads Agency Limited (SANRAL) annual reports	16. Integrated Transport System (ITS) Implementation Framework for Gauteng
Midvaal	Local municipality	53,353	64,271	95,301	8. Gauteng Management Agency annual reports	17. Ekurhuleni Metropolitan Spatial Development Framework 2011
Mogale city	Local municipality	226,446	295,505	362,422	9. METRO buses annual reports	18. CITP (Ekurhuleni, 2014)
Randfontein	Local municipality	107,711	128,842	149,286		19. Johannesburg Strategic Integrated Transport Plan, 2013
Westonaria	Local municipality	115,592	109,799	111,767		
South Africa	Republic	40,583,573	44,819,778	51,770,560		

Source: [20, 21].

Table 1. Overview of the secondary data sources consulted.

development philosophy as well as integration of activities [2, 4]. Spatial restructuring therefore manifests itself in terms of spatial development frameworks/physical plans/master plans and urban design plans aimed at redressing spatial inefficiencies and inequalities in an area, measures that promote public mass modes of transport over private motorist-based transportation approaches as well as urban development initiatives that support vertical (upward growth) rather than lateral (sprawling) urban development outcomes.

3.3. The notion, concept and theory of urban systems

The classical theory of urban systems recognises that urban elements that constitute the structure are in a state of equilibrium that promotes system efficiency and effectiveness [22]. If the assemblage components of an urban system are disturbed, the system will malfunction or become inefficient or operate at suboptimal performance creating repercussions that affect all system components. In this regard, the urban structure is viewed as a complex system with the following elements: size, function and scale; accessibility and movement; economic integration and pluralism of activities; ecological and environmental ecosystem services; infrastructure and services; and policy, institutions, governance and management arrangements. From the identified six (6) main elements, it is important to acknowledge that these components are interdependent, interrelated and interconnected. In any event, the functioning of these system components manifests themselves in terms of a 'territorial dynamics approach' with implications linked to centrality, specialty and peripherality of urban territories in any spatial setting.

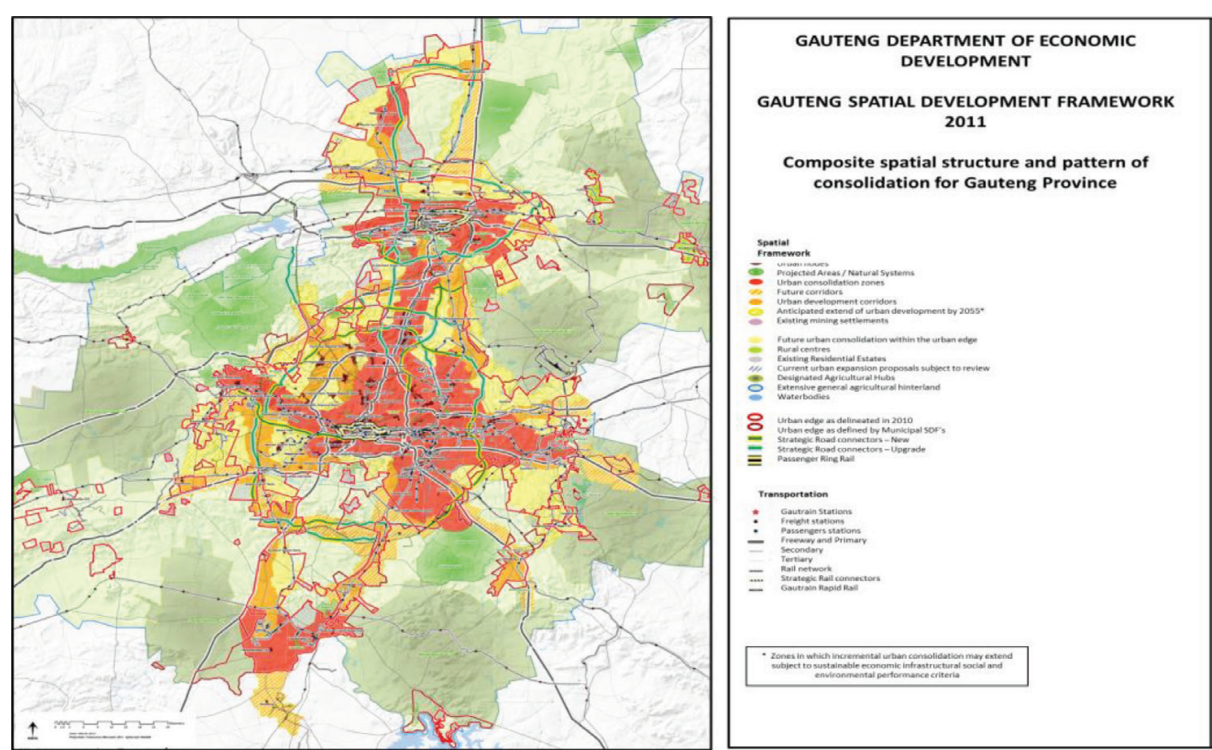
3.4. Urban polycentricism growth and management approach

Urban polycentricism growth and management approach draw its roots from the commuting models of polycentric and multicentric city structures [12, 23]. The polycentric commuting spatial model is predicated on the presumption that the city has an equal distribution and spread of sub-centres of employment of a similar scale that have the capacity and capability to generate trips from all over the city in all directions [7]. In this scenario, the characteristics of commuting with respect to spatial clustering and scattering are represented by a wide dispersion of scattered random origins and destinations, appearing almost everywhere. However, on the other hand the multicentric growth and management approach in acknowledging the existence of multiple sub-centres of commuting and spatial power introduces the overarching principle of primacy/dominant commuting and spatial attraction sub-centre. It is this dominant sub-centre that tends to explain the urban commuting and spatial structuring skewedness and abnormality regarding spatial inefficiencies, spatial fragmentation and transportation inadequacies in an urban setting [7, 11, 14]. The urban commuting flows would be composites of both random and radial patterns. In this regard, the poly- and multicentric urban growth and development paradigms lend themselves to spatial structuring approaches that require the need to generate solutions applicable to different multilevel systems of city scales, spatial and transportation governance, funding and partnership system. This is suggested as a way of developing and generating customised responses to rapid urbanisation in response to spatial and transportation needs.

3.5. Gauteng spatial development opportunity and constraint framework

Spatial planning in Gauteng province is managed through the Gauteng Spatial Development Framework among other development planning instruments as reflected on **Map 1**. The spatial plan represents a future desired spatial vision for Gauteng province. The spatial structure represented is an amalgamation of the common overarching development principles applicable to the individual local spatial development frameworks of all local authorities in the province.

From **Map 1**, we can deduce that the GSDF identifies several strategic initiatives destined for implementation between 2011 and 2030, which relate to urban structuring and priority action areas. These initiatives are regarded as the primary spatial focal points to act as catalysts in terms of significant urban transformation in Gauteng province over the next decade. The GSDF as reflected on **Map 1** is based on key spatial transformation development principles that have strong resonate in addressing the urban transportation bottlenecks in Gauteng province. The interventions are linked at the containment of urban sprawl by way of applying the urban edge principle, implementing a growth management strategy that seeks to advance compaction, residential densification and in-fill development within the existing urban fabric. At the same time, the approach is to advance social and economic integration of disadvantaged communities into the urban system, particularly those on the urban periphery. Central to all these initiatives is the promotion of the land use-public transport integration through nodal and corridor development. Evident from the above principles is the strong emphasis on public transport becoming the basis of the movement system in the province,



Map 1. Gauteng spatial development framework, 2011. Source: [24].

with urban corridors, activity spines and public transport routes creating the 'skeleton' for future processes of densification and intensification, including transit-oriented development around road and rail-based public transport facilities. However, challenges relate to the pace of implementing the transformative and catalytic projects that are linked to inadequate investment and funding framework. At the same time, the low population densities in the Gauteng province fight against the implementation of sustainable public mass transit systems. The fragmented local transport governance systems need to graduate into a Gauteng transport authority at a faster rate than what the Gauteng Transport Commission is operating at. While good intentions and initiatives are in place, these are falling short of addressing holistically the spatial and transportation inadequacies that characterise Gauteng province.

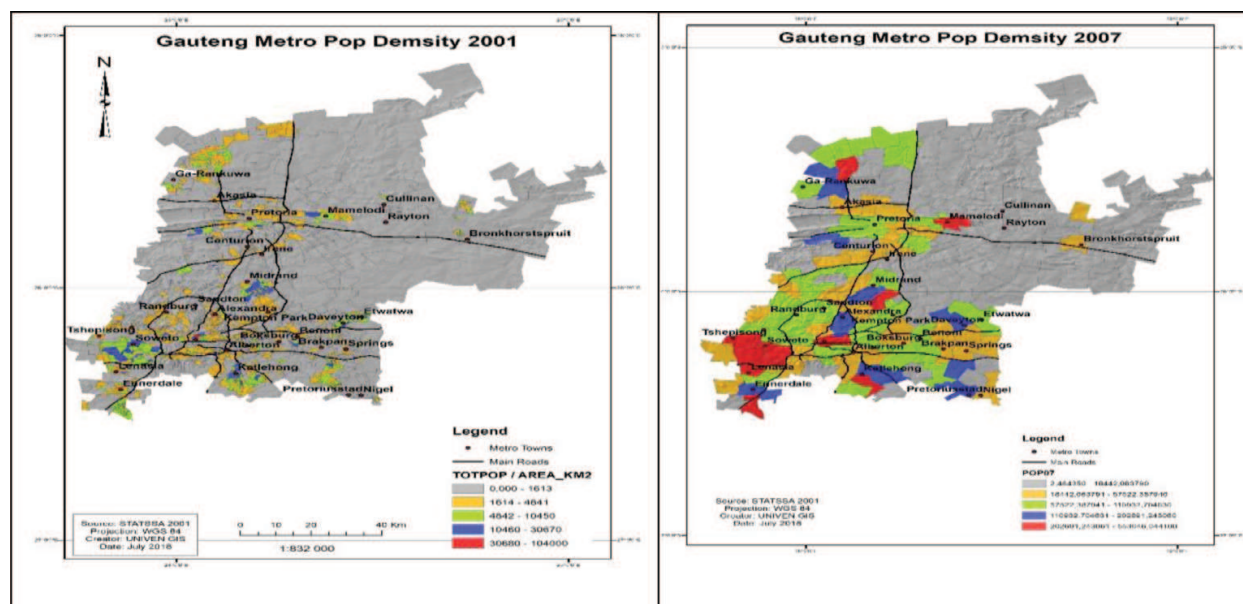
4. Results and discussion

In this section, the main findings of the study are discussed. These are covered in terms of the following subheadings: rapid urbanisation, high motorisation rates, spatial fragmentation and inefficiencies. The synthesis of the three above-mentioned areas is then presented in the form of a subsection that discusses the spatial and transportation complexities and challenges linked to reconciling rapid urbanisation challenges to a transportation solution. In any case, the section is then summarised through advancing recommendations and implications emanating from the study aimed at suggesting practical spatial and transportation solutions for the Gauteng city region in South Africa.

4.1. Rapid urbanisation

The overall growth rate of 30.7% between 2001 and 2011 (and a further 7.5% between 2011 and 2015) reflects high levels of in-migration into the Gauteng province [20]. This high growth rate is not only directed at the urban areas of the metros but also into the economic hubs of the local municipalities. Growth across the municipalities in Gauteng province has consistently varied from 9.7% in Emfuleni local municipality (LM) to over 35% in the city of Johannesburg (COJ) and city of Tshwane (COT), to 48% in Midvaal LM. The only municipalities to have experienced very low growth and negative growth rates between 2001 and 2011 census period were Westonaria LM (1.8%) and Merafong LM (−6.2%). Between 2002 and 2013, the household growth rate for the Gauteng province in total was 39%, while the next closest growth rate in South Africa was the Western Cape at 12.3% [20, 21]. Even Emfuleni LM in Gauteng, which had the lowest growth in household of all municipalities in the province (17.8%), exceeded the household growth rate of the Western Cape. **Map 2** illustrates spatially the change in total population per sub-place in Gauteng city region 1996–2011.

From **Map 2**, we can deduce that generally Gauteng city region experienced high population changes between 2001 and 2011 census periods. This high rate of growth in the number of households formation relates to the impact of in-migration, which is most pronounced in the Gauteng province, making the work of the Gauteng municipalities more than challenging. Mismatches, deficits, tensions and capacity constraints in providing for employment/



Map 2. Change in total population per sub-place in Gauteng city region 2001–2007. Source: [25, 26].

job creation, housing, facilities, transport infrastructures and services emerge as critical challenges as the region is underprepared for the rapid urbanisation wave occurring under its area of jurisdiction.

4.2. High motorisation rates

The national vehicle fleet in 2015 consisted of 10,317,262 registered vehicles, with 39% of all vehicles registered in Gauteng province. Passenger cars comprise 73% of vehicles registered in Gauteng province with heavy-duty vehicles (HDV) and buses collectively making up just 3.8% of the provincial vehicle fleet. **Table 2** presents a tabular illustration of the registered vehicles in the Gauteng province in the year 2015.

From **Table 2**, one can deduce that passenger cars are the largest vehicle category of registrations, while light delivery vehicles (LDVs) also form a significant component of the vehicle population. The total amount of diesel and petrol sold in South Africa was 13,492 and 11,470 mL, respectively. The amount of fuel sold in Gauteng in 2015 was 3160 mL of diesel and 4119 mL of petrol. The greater volume of petrol to diesel is reflective of the larger number of passenger cars in Gauteng province. The high automobile dependency on small and inefficient vehicles has negative implications in terms of urban road space utilisation, carbon footprint as well as

	Motorcycles	Passenger cars	LDV	HDV	Buses	Total
Gauteng province	147,958	2,975,065	781,714	136,220	19,112	4,060,069
National total	366,714	7,143,707	2,380,536	367,045	59,260	10,317,262

Source: [27].

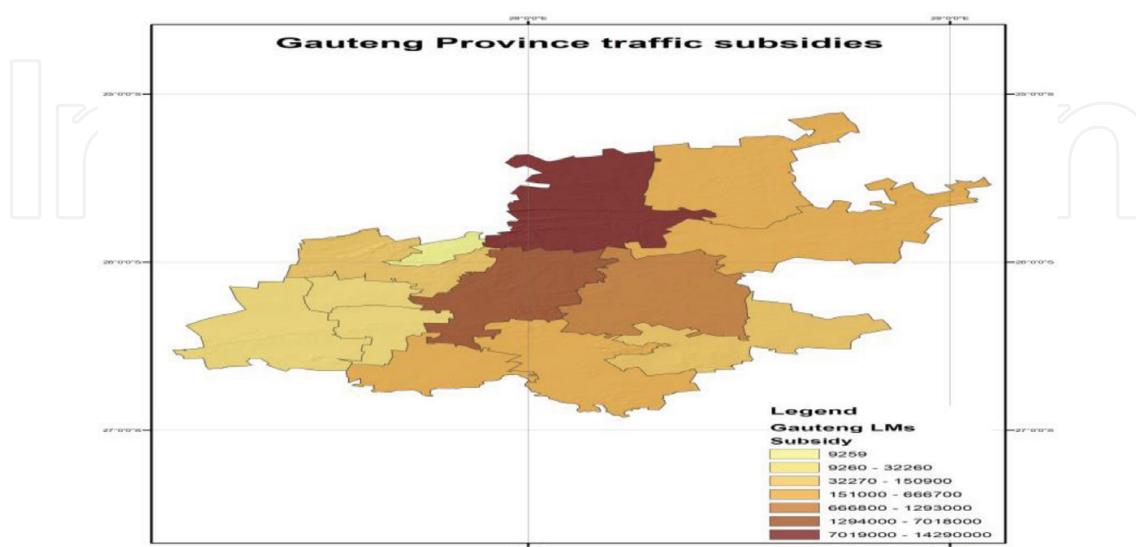
Table 2. Registered vehicles in Gauteng province in 2015.

congestion including road-based accident-related data. **Map 3** presents a spatial map illustrating the current public transport bus subsidy spatial portrait of subsidy allocation and distribution in South Africa. This is discovered to be strongest in the Gauteng city region around Pretoria, Johannesburg, Randfontein and Ekurhuleni.

From **Map 3**, we can deduce that the fragmented nature of spatial settlements in South Africa has huge implications for the current public transport subsidy policy by the government. The subsidies are highest in Gauteng city region as well as in Cape Town city, for example. Following on then, **Table 3** presents a comparison of the estimated annual emissions of air pollutants and CO₂ from registered motor vehicles in Gauteng than the national emission outputs. The CO emission of 440,22 t/a is the highest of the air pollutants and is equivalent to 35% of the national emission [28]. Emissions of non-methane volatile organic compounds (NMVOC) are relatively high and account for 35% of the national emission with the NO_x emission accounting for nearly 30% [28]. Emissions of lead are very low due to the phase-out of lead in fuels. Similarly, SO₂ emissions are relatively low with the low sulphur content in fuels. The total CO₂ emission for the national vehicle fleet is estimated to be 54,258,926 with 16,213,749 t/a from vehicles registered in Gauteng province, accounting for nearly 30% of the total CO₂ emission [28]. The city of Johannesburg, city of Tshwane and Ekurhuleni metropolitan municipality have the highest pollutant emission rates for all pollutants.

However, **Table 4** presents the total emissions of air pollutants and CO₂ by vehicle category in Gauteng province. The significant contribution from passenger cars to the CO emission is noteworthy, as well as their contribution and that of HDVs and buses to the NO_x emission.

From **Table 4**, we can deduce the automobile dependence cost on emissions in Gauteng province. Attempts at land and transportation solutions that move towards low-carbon economy are therefore a welcome development.



Map 3. 2018 public transport bus subsidy spatial representation in South African rand. Source: [25].

	NO _x	SO ₂	CO	PM ₁₀	NMVOC	Benzene	Lead	CO ₂
Gauteng province	74,015	1734	440,222	3313	63,921	105	0.15	16,213,749
National total	251,390	6952	1,241,295	13,646	184,161	319	0.53	54,258,926

Source: [28].

Table 3. Total emission of air pollutants and CO₂ from motor vehicles for 2015 in Gauteng in tons per annum compared with the national emission.

	Motorcycles	Passenger cars	LDVs	HDVs and buses	Total
NO _x	794	45,541	9861	17,819	74,015
SO ₂	16	340	896	482	1734
CO	40,967	391,189	4213	3853	440,222
PM ₁₀	226	985	1524	578	3313
NMVOC	9693	46,023	7434	771	63,921
Benzene	1.6	41.0	62.5	0.0	105.1
Lead	0.011	0.066	0.058	0.010	0.15
CO ₂	278,105	11,468,237	2,906,125	1,561,282	16,213,749

Source: [28].

Table 4. Total emission of air pollutants and CO₂ from vehicle classes in 2015 in Gauteng province in tons per annum.

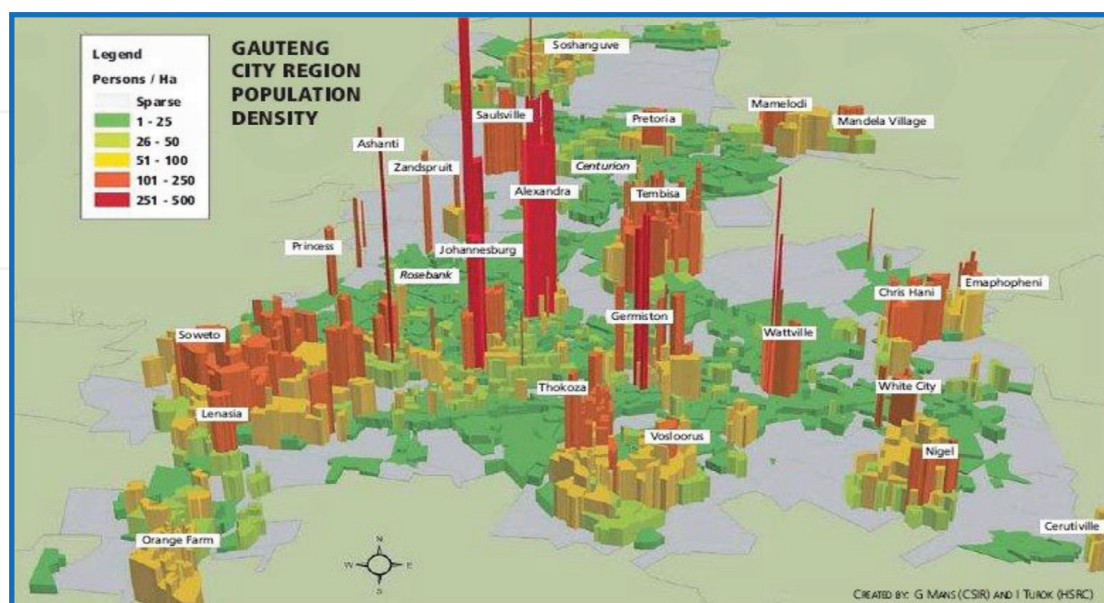
4.3. Spatial fragmentation and inefficiencies

In the South African context, there are three critical concerns in relation to urban form and density. First, densities overall are very low in international terms, resulting in high costs of infrastructure provision, long and costly travel for individuals, inefficient logistic networks and low market thresholds [13, 14, 29–32]. Second, the density gradient is frequently inverted: the highest densities are found in pockets of low-income settlements along the periphery, rather than closest to the urban centre [33]. Third, spatial fragmentation of the labour market disperses available work [34]. South Africa's metropolitan areas have an average density of 2960 people/km², than 8292 people/km² for low- and middle-income countries and 3100 people/km² for high-income countries [32, 35]. Internationally, the only cities with lower average densities than South African cities, and longer travel distances to work, are the sprawling cities of North America, which rely heavily on individual passenger cars rather than public transport [22, 36, 37]. A comparative analysis of Johannesburg metropolitan area with cities in developed countries shows that there is the existence of low density in Johannesburg which becomes a critical development problem. On average most Johannesburg residents live in townships far from the city centre [14]. This development pattern contrasts with the population distribution of other large cities, since density is usually greatest towards the city centre. Transport is a major

challenge in this type of urban environment [13, 29, 31]. Most people in Johannesburg live far from the city centre and their place of work. The high density in townships also presents service delivery challenges, and crowding reduces quality of life. A city cannot therefore be quickly restructured. However, the need for inner-city revitalisation, mixed-use development and densification in central urban areas is one way of resolving the issue. The need to focus development in townships in city planning and development is also vital. The Gautrain and surrounding development hubs are therefore a good step in this direction.

Map 4 captures density variations in the Gauteng province in a graphic manner. While such variations are not uncommon internationally, what is unusual in South Africa's case is the low densities in middle-class residential areas, than high densities on the urban periphery. Particular concerns include the extreme levels of dispersal within Gauteng, South Africa's economic heartland, which makes it difficult to operate as an integrated city region, and the persistence of the profoundly constrained pattern of 'displaced urbanisation', most clearly evident in Tshwane (Winterveld) and Mangaung (Botshabelo). However, since the early 1990s, a growing concentration of people living in inner-city Johannesburg has begun to counteract the distortion of a negative density gradient. In many cases, this is happening through informal process such as increased densities in informal settlements close to work and growing numbers of backyard shacks. **Table 5** presents relative transport modal splits for nine different countries.

From **Table 5**, one can deduce that Johannesburg is a relatively energy-inefficient city in global terms. Johannesburg has furthermore high levels of unemployment and poverty (around 25%) and is home to one of the highest Gini coefficients in the world (0.75 than 0.38 for Asian cities) [12, 23]. Transport accounts for 31% of SA's energy consumption (56% in cities) and 16% of CO₂ emissions [38]. The big transport modal split trend in the lower-income groups of South Africa has been the shift away from using publicly owned public transport (bus



Map 4. Population density in Gauteng province. Source: [35].

Urban area	Transport modal split			
	Public transport (%)	Walking (%)	Cycling (%)	Private motorists (%)
Istanbul	41	45	n/a	14
New York	56	11	1	30
Shanghai	19	29	25	22
London	37	20	2	40
Mexico	79	n/a	n/a	16
Johannesburg	32	31	≤1	37
Berlin	27	25	10	37
Mumbai	36	56	1	5
Sao Paulo	32	33	1	29

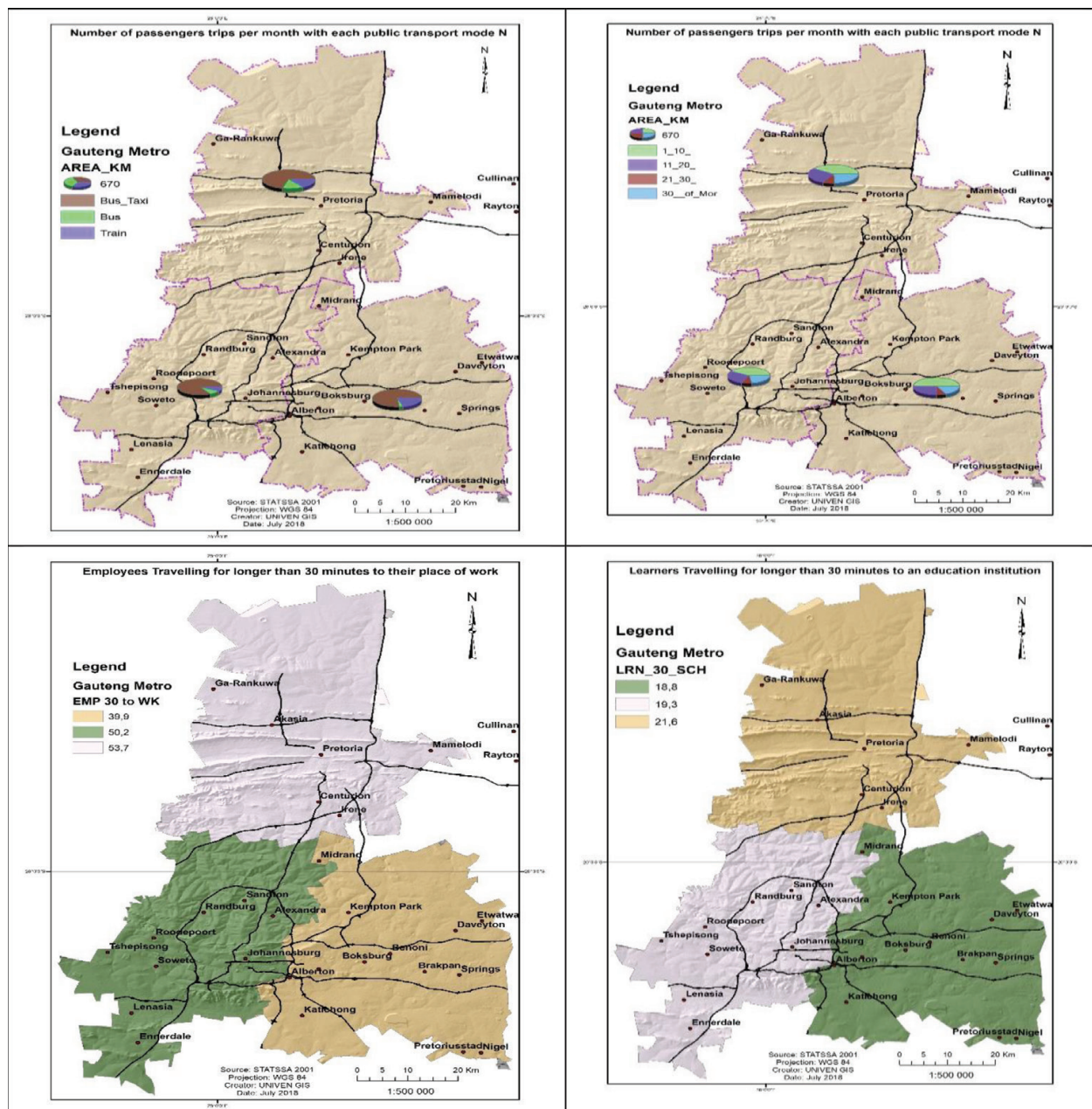
Source: [35].

Table 5. Relative transport modal splits in nine different countries.

and rail) to privately owned public transport (taxis). As an example in Gauteng, changes and trends in public transport were recorded with respect to the use of minibus taxis increased from 3% in 1975 to 41% in 2009 with bus declining from 22 to 4% and train from 20 to 8%. At the same time, despite the travel flexibility associated with taxis, travel times for this group have remained static or declined in places. However, a worrying development is the fact that the middle-income group has remained resolutely car-oriented and travel times have increased dramatically since 1980 (nearly 60%) [39, 40].

From **Map 4**, we can deduce that there is a challenge of spatial distribution of population in Johannesburg. The underlying factor is that Gauteng province is not densified than other cities in the World. The spatial fragmentation manifests itself in spatial mismatches between residential areas and areas of economic opportunity. This has also strong resonates with constrained transportation and commuting challenges [41]. Given these spatial inefficiencies and misfits, transport costs and modal choice are constrained generally for passengers but in particular for employees and learners who use public transport. **Map 5** presents transport indicators by metro in South Africa which has resonates with the spatial and transport inefficiencies.

The high cost of transportation is partly due to spatial form and partly to do with modal splits and inefficiencies affecting particular types of transport (refer to **Map 5**). Internationally, spatial planning methods, such as transit-oriented development (TOD), have been developed and are touted as the antidote to address the spatial and transportation disjuncture as illustrated in Gauteng. The cities in Gauteng province are typically ‘sprawling cities’ that were not originally planned, designed and built to meet the needs of a large majority of the commuting population. A way of addressing this anomaly is through devising and crafting an urban development agenda that places at the centre the integration of public transport with the built environment as paramount. Steps towards building compact, inclusive, resilient,



Map 5. Spatial representation of transport indicators by metro in Gauteng province. Source: [20, 21, 25].

integrated and connected cities are part of the solution package aimed at enhancing commuting experiences in Gauteng. In South Africa these principles have been acknowledged and the need to foster a strong and conducive environment suggested. Grant frameworks can be used to encourage densification and facilitate transition to a low-carbon economy in Gauteng province in particular and South Africa by extension. A major plank of the spatial transformation necessary in South African cities is densification—people moving from the periphery to the centre—and the formation of ‘mobility corridors’ [33, 42, 43], for those who remain outside the centre.

4.4. Reconciling rapid urbanisation challenges to a transportation solution

Rapid urbanisation further complicates the realisation of a sustainable transportation solution in Gauteng province. This is because the government has to respond to many issues including the housing backlog matters, growing informalities in the cities which also manifest themselves in expanding and expansive informal settlements. At the same time, an unemployment challenge is also created and continues to remain stubbornly high (estimated at 35%) [20]. In this set-up priority matters become housing, employment, provision of socio-economic facilities, fighting crime and increasing security, while transport features in the low rungs of priority matters. As an example, in the 1970s, it was identified and costed that an underground tube transport was solution for the transportation matters in Gauteng province. The project was however not implemented because it was seen as too costly requiring US 7 billion dollars at that time [13]. Parallel to the implementation of the Gauteng rapid rail link in the build-up to the 2010 World Cup, the idea of a light tram system to complement the Gautrain as well as existing conventional bus services and taxi transport systems was also mooted. However, the project was terminated at an advanced stage of preparing the logistics for its implementation owing to the fact that necessary government project approval and protocol compliance matters had been overlooked. While the Gautrain rapid rail link project has been implemented, the project suffers from having an inadequate and incomplete geographic coverage and spread to provide all-round transport system to all areas. In any case, the BRT systems for the three metro are at various stages of implementation with the BRT *Rea Vaya* (Johannesburg) running, while Tshwane *Areyeng* is also in operation. The BRT *Harambee* (Ekurhuleni) is yet to commence operation. While all these transformation and advanced new generation of transport systems are welcome, there is still need to improve the integration between the modes through switching and implementing the single public transport ticket system. In addition, to make public transport more sustainable from a funding perspective and growing sales, there is need to densify the public transport corridors which are currently lowly populated. The Gauteng improvement freeway programme that was implemented by the government with tolling as a principle to manage road space in Gauteng province has met with spirited resistance from the road users with toll paying defaulting rates stand at approximately 78% of the road users. Different stakeholders have continued to argue that the project though welcome was not properly structured. Its introduction to the commuters at least regarding public participation and funding and sustainable models for repaying the loans has been singled as having been inadequately structured and conveyed to stakeholders. At the same time, a sustainable steering and integration model that is acceptable to the minibus taxi industry is still yet to be developed and agreed on. Overall, rigorous efforts towards spatially transforming Gauteng city form from fragmented structure into a compact transit-oriented driven spatial structure are fundamental if the transportation and spatial inefficiencies in Gauteng are to be redressed. In this set-up in which the public system is yet to establish itself as the choice of commuters, the growth in car ownership continues unabated. The consequence is the vicious loop of an automobile-dependent society in the Gauteng province. While land densification programmes and initiatives in place are acknowledged, the downside to the arrangement is that these are inadequate in terms of the scale, size and desired impact to witness a significant change in travel patterns, driving behaviour as well as new housing and building density set-ups. At the

same time, the use of separate transport systems and institutions by the local municipalities creates cracks and lack of transportation integrated solutions in the Gauteng city region. This is because each municipality plans and implements spatial and transportation projects as if it is isolated and not linked to each other in the bigger Gauteng province transport set-up and spatial dynamics network of settlements, industry and commercial enterprise.

4.5. Recommendations, implications and emergent issues

From this review, it can be recommended that resolving the urban spatial and transportation solutions in Gauteng province requires a mixture of both spatial and transportation and non-spatial and transportation solutions. Optimising public transport is one way of addressing the transport commuting constraints in Gauteng province [44, 45]. The need for transforming Gauteng province into a smart city region through the smart bus rapid transport (BRT) systems should be upscaled to cover all aspects of a smart city and metropolitan region such that we have a city landscape supported by smart planning systems, smart building and construction systems, smart infrastructure maintenance and rehabilitation systems, smart recording and system management systems, smart information and communication system, et cetera [46, 47]. All these initiatives should enable increased accessibility of the Gauteng city region so that the productivity and competitiveness of the region are increased [48]. The need to consolidate governance and transport authority systems that can migrate, integrate and plan for all the transport needs of Gauteng province holistically and comprehensively in terms of a transport authority for the region rather than single areas requires further improvement and is an initiative in the right direction. Such transport authorities have been seen to assist in managing urban transport and spatial planning better in areas such as the Greater London region in the United Kingdom as an example [49–54]. The region is therefore encouraged to find the right balance in terms of implementing advanced spatial planning systems that reverse spatial fragmentation problems, making use of smart transport solutions to solve the transport problems of lack of integrated pricing system as well as fully develop and implement a transport authority that provides the overall intelligence to address today's transportation problems while having a master plan to address the future transport problems in the Gauteng region.

5. Conclusions

This chapter has managed to illustrate the multiple and complex spatial and transportation challenges that the Gauteng city region faces and is faced with. These challenges are partly explained by the fact that the Gauteng city region forms an extended economic hub and network of socio-economic opportunities and activities. This unique status of Gauteng city region accounts for high in-migration which creates differential pressure on all facets of socio-economic infrastructure and facilities. In response to the high urbanisation and motorisation rates experienced in Gauteng city region, the municipalities have developed a range of spatial and transportation interventions to resolve spatial fracturing, fragmentation, dislocation and urban traffic congestion problems. The interventions have met with

mixed fortunes from an implementation perspective, although generally the sum effect of these interventions is the development of strategic forward-looking urban structure and transportation solutions. While the expansion of freeways through road construction and highway expansion (physical instrument) is appreciated, the downside of this intervention is that it supports a predominantly automobile-dependent growth at the expense of development of other equally important transport dimensions such as improving the metrorail, expanding and popularising urgently the Gauteng rapid rail link as well as the development of transit-oriented development (TOD) to facilitate a compact and pedestrian urban and friendly urban structure. The introduction of e-tolling of roads (financial instrument) has met with spirited resistance, and the matter remains largely unresolved. The debate points have revolved around inadequate consultation and participation during the build-up of the project; at the same time, the economic funding model has been questioned as inappropriate. Suggestions have ranged from increasing a fuel levy nationally to having a special fuel tax for Gauteng city regions, while others have argued that the government should fund the budget from the income tax paid by individuals and companies, respectively. From this chapter's review, the need for continued research and development aimed at delivering more efficient and carbon-neutral spatial and transportation solutions beckons. It is also high time that the autonomous and electric vehicle/buses technology and implications regarding reconfiguration and spatial planning and organisation of land-use debate should be allowed to take centre stage. A sustainable spatial and transportation approach for the Gauteng city region is one that is anchored on providing innovative solutions to addressing current problems as well as balancing future intelligent innovations to create an adaptive, progressive and robust spatial structuring set-up that can be adequately supported by appropriate transportation solutions. In any case, the solution to the spatial structure mismatches, disconnects and transportation inadequacies does not lie solely in the domain of spatial and transportation planning and management per se. The need to outreach and create space for a multi-, trans- and cross-disciplinary integrative and cooperative partnerships is crucial in achieving the anticipated spatial and transportation turn linked to advanced forms of the next generation of spatial and transportation solutions. Indeed, restructuring the Gauteng city region from a spatial and transportation perspective is a daunting task, which however requires attention and can be tackled with the application of a clear spatial and transportation implementation road map plan, supported by an adequate provision of resources (financial, economic, human, political support and dedicated leadership) within the orbit of an appropriate institutional and governance delivery system and framework.

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Conflict of interest

The authors make a no 'conflict of interest' declaration.

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