THE ASSOCIATION BETWEEN TRANSPORT NETWORK LENGTH AND ECONOMIC ACTIVITY: A CASE STUDY OF CAPE TOWN

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ABSTRACT

Public transport is the main mode of transport in South Africa. Yet, the availability of it, or lack thereof, is the main transport-related problem for South Africans (Statistics South Africa, 2021). Adding to inadequate public transport is its insufficient network length. An overwhelming amount of research has studied the association between road network length and economic output at a national level. This study fills a knowledge gap by researching the association between economic activity and various types of network lengths, including public transport, at a city level. The results show a moderate to strong positive association in Cape Town depending on the transport network type. The results infer that more economic activity is associated with a kilometre of formal public transport compared to informal public transport. It also provides economic justification for expanding transport networks in certain regions within the metro. This includes the expansion of the MyCiTi service to the Southern and Cape Flats regions of Cape Town via its anticipated Phase 2A service. The results can inform budgetary decision-making and funding allocation through planning and policy documents.

1. INTRODUCTION

When transport infrastructure and public transport services are available, it paves the way for people to engage with one another and with economic activities. “Transport networks are essential arteries of a vibrant economy, and a catalyst for development and economic growth”, as stated in the South African National Land Transport Strategic Framework of 2023-2028 (NDoT, 2023). When transport networks are limited in length or coverage, it negatively impacts the labour market, economic activity, and social equity (DBSA, 2024). It is therefore not surprising that a lot of attention has been paid to length of road network and its association with economic output. What has not received sufficient attention is the association between the length of public transport networks and economy activity at a city-level.

Ongoing environmental concerns over efforts to increase transport availability is evident. This is because transport availability is usually associated with the construction of new roads and the provision of more public transport services. While these concerns are valid, economic development lags behind when transport availability does not increase with population size. In fact, the main concern of user-perceived transport problems in South Africa, including Cape Town, is not transport cost, congestion, or road conditions, but a lack of public transport availability (Statistics South Africa, 2021). Consequently, environmental concerns over increased transport availability makes a critical review of the economic importance of transport availability timely.

This research paper explores the association between transport availability, in terms of network length, and economic activity. It quantifies the size and direction of this association not just for roads, but for public transport services as well, in Cape Town. Section 2 reviews existing relevant literature, identifying knowledge gaps. Using the data and methodology approach as described in section 3, section 4 presents empirical results which includes spatial analysis, correlation analysis and regression equations. Section 5 discusses the results and concludes in section 6 with transport funding allocation recommendations, at regional level in Cape Town.

2. LITERATURE REVIEW

2.1 Key Inferences From the Literature

The association between road and rail transport network length and economic output has been well researched over the past few decades (Zhang & Cheng, 2023). A review of nearly one hundred research papers suggests that the majority of researchers use length of road and railway in kilometres, kilometres per capita or kilometres per square kilometre as a measurement indicator. Key inferences from the literature include:

1. A positive, instead of a negative, association between transport network length and economic output exists (Njoh, 2000; Kusideł & Górniak, 2012; Farhadi, 2015; Amairia & Amaira, 2017; Melo, Graham, Levinson & Aarabi, 2017).
2. This association is stronger in high-income countries/provinces, versus low- and middle income areas (Queiroz, Haas & Cai, 1994; Matas, Raymond & Ruiz, 2018).
3. This association (point 1) applies to the South African context (Perkins, Fedderke & Luiz, 2005; Cheteni, 2013; Hlotywa & Ndaguba, 2017).

To support each inference above, key research papers are discussed below. These were selected since they inform the methodology of this research paper.

Queiroz et al. (1994) and Queiroz and Gautam (1992) examined the association between road network length and economic output at country level. The study area consisted of 98 countries and the data is representative of the year 1988. Empirical results from cross-sectional analysis were derived. This included scatterplot analysis from which an equation was extracted to illustrate the significant positive relationship between per capita length of paved roads (PLPR) and per capita Gross National Product (PGNP). This relationship is depicted in Equation 1. Since the y-intercept term in the original equation was not found to be significant at the 0.01 level, they removed it from the equation and accordingly adjusted the R squared value to 0.76.

$$PGNP = 1.39PLPR \quad (1)$$

According to Queiroz and Gautam (1992), two conclusions can be derived from Equation 1. Firstly, the average PGNP for each millimetre of paved road in a country is equal to the coefficient in Equation 1 ($1.39). Secondly, the adequacy of the length of paved road stock a country is relatively inadequate when the ratio between PGNP and PLPR of a country is more than the coefficient in Equation 1 (1.39). In other words, these countries have a relatively inadequate supply of paved roads compared to, and to support, economic output.

Kusideł and Górniak (2012) examined the association between transport availability and economic growth. The study area was Poland, and the data is representative of the years 2004 and 2009. A synthetic indicator of transport availability was developed using selected variables characterising road and rail transport. These variables included length of road and rail networks measured in kilometres per 100 km^2. The spatial unit of analysis was voivodships (similar to provinces). Spatial representation of transport availability was developed and is depicted in Figure 1. Empirical results revealed a positive statically significant relationship between transport availability and economic growth in all voivodships in Poland as determined by correlation coefficients ranging from 0.5 to 0.6 per voivodships.

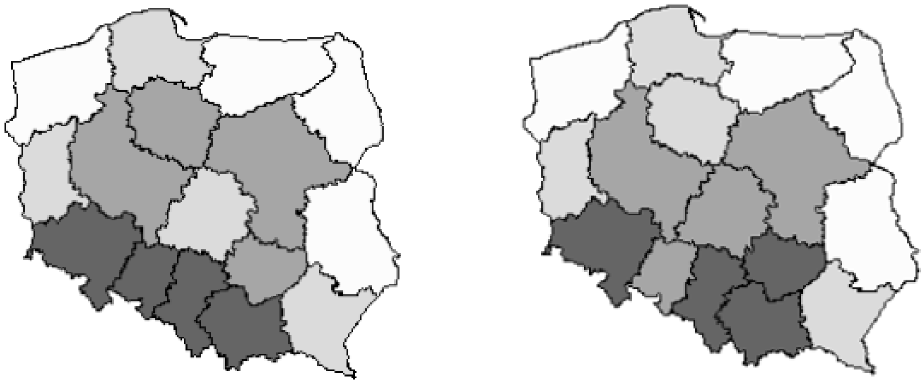

Figure 1: Spatial representation of transport availability for passengers (left) and goods (right) in Poland in 2009 (Kusideł & Górniak, 2012)

Njoh (2000) examined the association between road network length and economic output. The study area consisted of 36 sub-Saharan African (SSA) countries and the data is representative of the year 1988. Empirical results from cross-sectional analysis revealed a positive statically significant relationship between PLPR and PGNP in the 36 SSA countries as determined by a correlation coefficient of 0.46. The correlation coefficient increased to 0.60 for roads in good condition. The correlation coefficient appears to be stronger when the time range is expanded to include the mid-1900s. For example, Perkins et al. (2005) estimated a correlation coefficient of 0.996 for length of paved road and economic growth in South Africa for the period 1938 to 2001.

2.2 Driving Forces

This sub-section aims to explain the driving forces behind the positive association between transport network length and economic output. According to the endogenous growth theory, long-run economic growth largely depends on the provision of infrastructure, particularly road infrastructure (Barro & Sala-i-Martin, 2004). Hlotywa and Ndaguba (2017) interprets this as any infrastructure investment is crucial for economic growth, but that infrastructure investment in transport specifically creates the highest number of economic opportunities. Both the endogenous growth theory and the Solow-Swan model argues that the nature of improved technology, accessed by investment, drives economic growth (Hlotywa & Ndaguba, 2017). This suggests that when the transport network length of an area is adequate or sufficient, modernisation through technological advances and innovation of the current transport system will also drive economic growth.

Figure 2 illustrates the conceptual framework that explores the association between economic growth and transport availability measured by transport infrastructure investment, modernisation, and innovation. Transport infrastructure investment involves the allocation of resources for the development, maintenance, and improvement of physical transport infrastructure. This includes the expansion of transport networks with roads and railways. Modernising of transport involves upgrading vehicles and intelligent transport systems to improve efficiency. Innovation in the provision of services and supply involves leveraging existing supply better. This includes the expansion of public transport networks by granting more operating licenses to public transport operators to function on existing transport infrastructure.

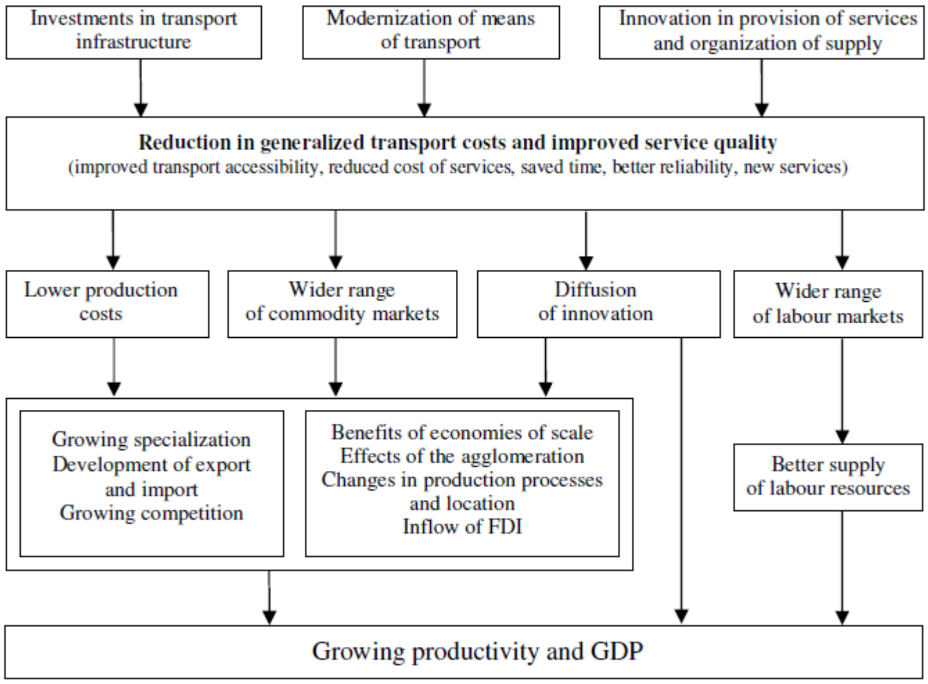

Figure 2: Conceptual framework of the association between transport availability and economic growth (Koźlak, 2017)

Improved transport availability due to investment in infrastructure, modernisation and innovation generates direct and indirect economic effects (Zhang & Cheng, 2023). Direct economic effects stem from transport cost and time benefits for goods and people (Mohmand, Wang & Saeed, 2017). It includes effects such as savings on vehicle operating costs and savings on the opportunity cost of time, especially for car to public transport switchers (Weisbrod & Reno, 2009). Indirect economic effects occur outside the transport sector. These effects have been captured to some extent as part of conventional transport appraisal known as wider economic impacts (Koźlak, 2017). According to Graham and Gibbons (2019) wider economic impacts of improved transport availability can include:

1. Agglomeration economies since transport availability increases the scale of economic interactions available in the economy.
2. Tax revenues arising from labour market impacts since the labour market size and quality thereof can improve due to improved accessibility.
3. Imperfect competition since output is expanded due to decreased cost of interacting in the spatial economy.

According to Mohmand et al. (2017), direct and indirect economic effects transfer to end-consumers in various ways. This includes lower prices, increased output, increased corporate profit which may boost corporate investment level and thereby increase employment opportunities. Ultimately, Figure 2 suggests that improved transport availability leads to economic growth.

2.3 Causality

While there seems to be consensus about the positive association between transport availability or transport network length and economic output (Njoh, 2000), doubts are raised over the direction of causality (Koźlak, 2017). Does an increase in transport network length cause economic activity, or vice versa? Perkins, Fedderke and Luiz (2005) refers to this relationship as analogous to that between a building and its foundation - transport infrastructure (e.g. roads) typically exist not for its own sake but rather to support economic activity. However, economic activity financially supports transport infrastructure expenses since government income from economic activity finances transport projects. Consequently, this raises the question of bidirectional causality instead of unidirectional causality. The causal link between road and rail transport network length with economy growth has been investigated in a limited number of research papers. Key inferences from Perkins *et al.* (2005), Mohmand et al. (2017), and Zhang and Cheng (2023) include:

1. Bidirectional causality, instead of unilateral causality, is more likely to occur in higher-income countries or provinces, compared to lower-income or developing areas.
2. Bidirectional causality is more likely to occur in the long-run versus to the short-run.
3. In the short run, either unidirectional causality from economic growth to transport network length (high-income areas), or no causality (low-income areas) is observed.

Perkins et al. (2005) examined the association between transport availability, including transport network length, and economic growth. The study area was South Africa, and the data is representative of the years 1938 to 2001. Pesaran, Shin and Smith (PSS) F-tests were used to establish causality. Empirical results revealed long-run unidirectional causality from economic growth to length of road and railways. Bidirectional causality was observed, but only for freight transport in terms of the number of road vehicles and rail rolling stock used for freight transport. Only unidirectional causality is observed from economic growth to passenger transport in terms of number of road vehicles and rail rolling stock used for passenger transport.

2.4 Literature Gap

Although doubts are raised over the direction of causality (Koźlak, 2017), Perkins et al. (2005) already examined the causal association between transport network length and economic growth in South Africa. More recently, Cheteni (2013) and Hlotywa and Ndaguba 2017) attempted to establish the causal association between road transport investment and economic growth in South Africa. However, they did not derive a statistically significant conclusion in terms of causality. Causality testing is out of scope for this research paper. Instead, this paper addresses the literature gap as it relates to public transport. It quantifies the association between different types of public transport with economic activity, versus roads, without implying causality. Emphasis is placed on public transport since:

1. Researchers tend to aggregate road-based public transport and road-based private transport together by examining the association between road network length and economic output. In doing so, conclusions are not made about the association between economic output and different types of road-based public transport. Consequently, a literature gap exists on the association between economic output and bus rapid transit (BRT) versus scheduled bus versus informal public transport.
2. Knowledge of the economic activity (measured in Rand value) that is associated with public transport expansion (per public transport type) can act as economic return on investment justification for subsidised public transport network expansion expenses.

City-specific research of the association between transport network length and economic output is limited. In this regard, research output is mostly country specific (see sections 2.1 and 2.3). When this type of research is not at a provincial, municipal or city-level, it is difficult to make recommendations on government funding allocation to transport network length expansion projects within a country. Relatively recent published open data has made it possible to conduct analysis on the association between transport network length and economic activity in the City of Cape Town, for different transport network types. This research comes timely since South Africa's National Public Transport Subsidy policy is in its public participation phase at the time of writing.

3. RESEARCH DESIGN

The research design is informed by the research question: What is the association between the network length of different types of public transport and economic activity versus roads in the City of Cape Town?

3.1 Data

Based on the research question, data for two key categories is required, namely transport network length and economic activity. In terms of the prior, two principal types of data have been employed in previous studies (Zhang & Cheng, 2023). The first type includes measures of government transport investment in monetary terms. The second category includes measures of physical transport in terms of length of transport network in kilometres. For the purpose of this paper, the second category is preferred over the first category. Bougheas, Demetraides and Mamuneas (2000) and Palei (2015) explain that physical indicators of transport is preferred over monetary indicators in SSA context due to bureaucratic inefficiency or corruption with monetary investments. Consequently, and similar to other research papers (see sections 2.1 and 2.3), this research paper investigates transport network length in kilometres.

The second key category, economic activity, is measured by Gross Value Added (GVA). The main reason for the selection of economic activity (GVA) instead of economic growth (GDP) is because GDP is a measurement of economic output for a country as a whole, or a province. At city-level, GVA is better suited than GDP because GVA is a measurement of economic output at city level (Karuri-Sebina, 2016). GVA is broadly similar to what is more generally known as Gross Geographic Product (GGP) (CSIR, 2016). In essence GVA (at basic prices) = Compensation of employees + Gross Operating Surplus + tax on production - subsidies on production (Quantec, 2024).

The following constitute the principal data sources for the two key data categories, namely transport network length in kilometres and economic activity as GVA values:

1. The Council for Scientific and Industrial Research (CSIR) provided a shapefile that demarcates South Africa into 25 048 spatial units called mesozones[1]. Though not uniform in size, each mesozone contains a GVA value. The shapefile was used to demarcate Cape Town into 58 mesozones, each containing a GVA value.

[1]Gross Value Added data per mesozone in South Africa can be accessed via the SA CSIR MesoZone 2018v2 dataset: http://stepsatest.csir.co.za/socio_econ.html. Mesozones were determined by the CSIR though an algorithm that incorporates dasymetric mapping principles (CSIR, 2016). Dasymetric mapping transforms data from aggregate datasets to depict underlying statistical surfaces, utilising separate but related ancillary datasets. This method, closely linked to interpolation, enhances the detail of choropleth maps below local municipal level and mesozones do not overlap with multiple local municipality borders.

2. The City of Cape Town provided shapefiles from its Transport Data Warehouse that depict the transport route networks of roads, formal and informal public transport in Cape Town[2]. These shapefiles were used to calculate the length of various types of transport networks in kilometres in Cape Town per mesozone.
3. Geofabrik used data from OpenStreetMap to provide a shapefile that depicts the road network of South Africa[3]. This shapefile was used to calculate the length of road network in kilometres in South Africa per mesozone.

The following constitute the four main variables derived from the principal data sources:

1. EA: Economic activity measured as GVA in Rand value per mesozone.
2. LR: Length of the road network in kilometres in Cape Town (CPT) per mesozone.
3. LFPT: Length of the formal public transport network in kms in CPT per mesozone.[4]
4. LIPT: Length of the informal public transport network in kms in CPT per mesozone.

The aforementioned economic activity and transport data is cross-sectional in nature since it is representative of the year 2018. This reference year was selected mainly because GVA reliable data at lower than city-level (mesozone) was available for 2018, but not for other years at the time of writing.

3.2 Methodology

The cross-sectional nature of the available data limits the type of analysis to quantify the association between transport network length and economic activity in Cape Town. The type of analysis that this paper includes is three-fold.

Firstly, spatial analysis is conducted by developing maps in ArcGIS Pro to illustrate economic activity and length of transport networks in Cape Town. Kusideł and Górniak (2012) explains how maps can be used to illustrate transport availability by colouring in polygons based on their length of transport network (see section 2.1). Similarly, this paper uses this approach to develop maps that illustrate economic activity and transport network length of roads, formal and informal public transport in Cape Town. This is because polygons, in the form of mesozones, are coloured in based on their GVA value and their length of transport network per network type. A limitation of the aforementioned described analysis is the inability to deduce a concrete association based on maps. This limitation requires further analysis to be conducted which can include correlation analysis.

Secondly, Pearson correlation analysis is derived from SPSS. Tabachnick and Fidel (2013) explains that correlation analysis is frequently used to measure the association between two variables since it measures the size and direction (positive or negative) of the relationship between two variables. The correlation coefficient derived from Pearson correlation analysis ranges between +1 and -1, where a correlation coefficient close to .00 represents no linear relationship. Similar to Njoh (2000), Perkins et al. (2005) and Kusideł and Górniak (2012) (see section 2.1), this research paper uses Pearson correlation

[2]Versions of the shapefiles can be accessed from the Open Data Portal of the City of Cape Town: https://odp-cctegis.opendata.arcgis.com/search?tags=transportation.
[3]Versions of the shapefiles can be access from the OpenStreetMap or Geofabrik websites: https://download.geofabrik.de/africa/south-africa.html
[4]Where possible, formal public transport was analysed per mode (e.g. section 4.2). Formal public transport investigated includes bus rapid transit (BRT: MyCiTi), government-subsidised scheduled bus services (bus: Golden Arrow Bus Services) and passenger rail (rail: Metrorail).

analysis to quantify the size and direction of the association between length of transport network and economic activity. A limitation of correlation analysis is that it cannot infer causality since the dependent and independent variables are not specified.

Thirdly, regression equations are derived from scatterplots in SPSS by using its curve estimation function. Queiroz and Gautam (1992) explains that two conclusions can be derived from regression equations (see section 2.1). These equations are derived by fitting a linear line to a scatterplot. Economic activity is specified as the dependent variable and length of transport network as the independent variable for curve estimation. The constant term (or y-intercept) is excluded since it is not significant at p-level 0.05. Based on regression equations, this paper determines the GVA, in Rand value, that is associated with each kilometre of road, formal and informal public transport in Cape Town. Furthermore, this paper deduces a rough estimation of the adequacy of different transport network types in terms of its adequacy to support economic activity in eight spatial regions of Cape Town[5]. Based on the work of Queiroz and Gautam (1992), this is determined by comparing the ratio between economic activity and transport network length of a region to the coefficient of the regression equation. However, not much research has been published to justify such interpretation although it was developed by a well-published author, Cesar Queiroz.

The methodology of this paper includes normalisation of the data. The data, as described in section 3.1, is at mesozone level. Each mesozone is not uniform in size but ranges from 25 km^2 to 50 km^2. Consequently, spatial economic activity density and spatial transport network density is derived. The prior is computed by dividing GVA of a mesozone by the area size of the mesozone and multiplying this value by five. Similarly, spatial road density, for example, is computed by dividing the road network length in kilometres in a mesozone by the area size of the mesozone and multiplying this value by five.

The logical explanation for the multiplication by five relates to the argument that most Capetonians' economic activity is within a 25 km radius from their place of residence. This multiplication decision is also based on Kusideł and Górniak (2012) who multiplied by 100 to compute the spatial road density per 100 km^2 for each voivodship/province in Poland (see section 2.1). Normalisation of the data by area size is suitable for the first two types of analysis described above. However, for regression equation estimations, normalisation of the data by population size was deemed more suitable compared to areas size. Queiroz et al. (1994) made a similar conclusion and consequently normalised the data by population size instead of area size.

4. RESULTS

4.1 Spatial Analysis

Figure 3 consists of maps that depict spatial economic activity density and spatial transport network density for roads, formal and informal public transport in Cape Town. Class intervals, as shown in the map legends, are classified by the quintile method[6]. While the data is at mesozone level, the unit of analysis is regional.

[5]The classification of the eight spatial regions in Cape Town is the same as that used by Quantec (2024) and by the City of Cape Town for its District Spatial Development Frameworks. This classification is based on the municipal ward demarcation of 2016 by the Municipal Demarcation Board of South Africa.

[6]The quintile method distributes the observations equally across the class interval, giving unequal class widths but the same frequency of observations per class.

The below maps indicate that regions with the highest spatial economic activity density are the Table Bay and Tygerberg regions. Similarly, these regions have the most spatially dense transport networks, as measured by length of transport network in kilometres per 5 km^2 area. At the same time, the low-income, less economically active but highly populated regions of Khayelitsha, Mitchell's Plain and the Cape Flats also have some of the most spatially dense transport networks. Conversely, on the urban peripheral, both economic activity and transport network length are less spatially dense. Consequently, the results of Figure 3 suggests that the direction of the association between spatial economic activity density and spatial transport network density is positive instead of negative.

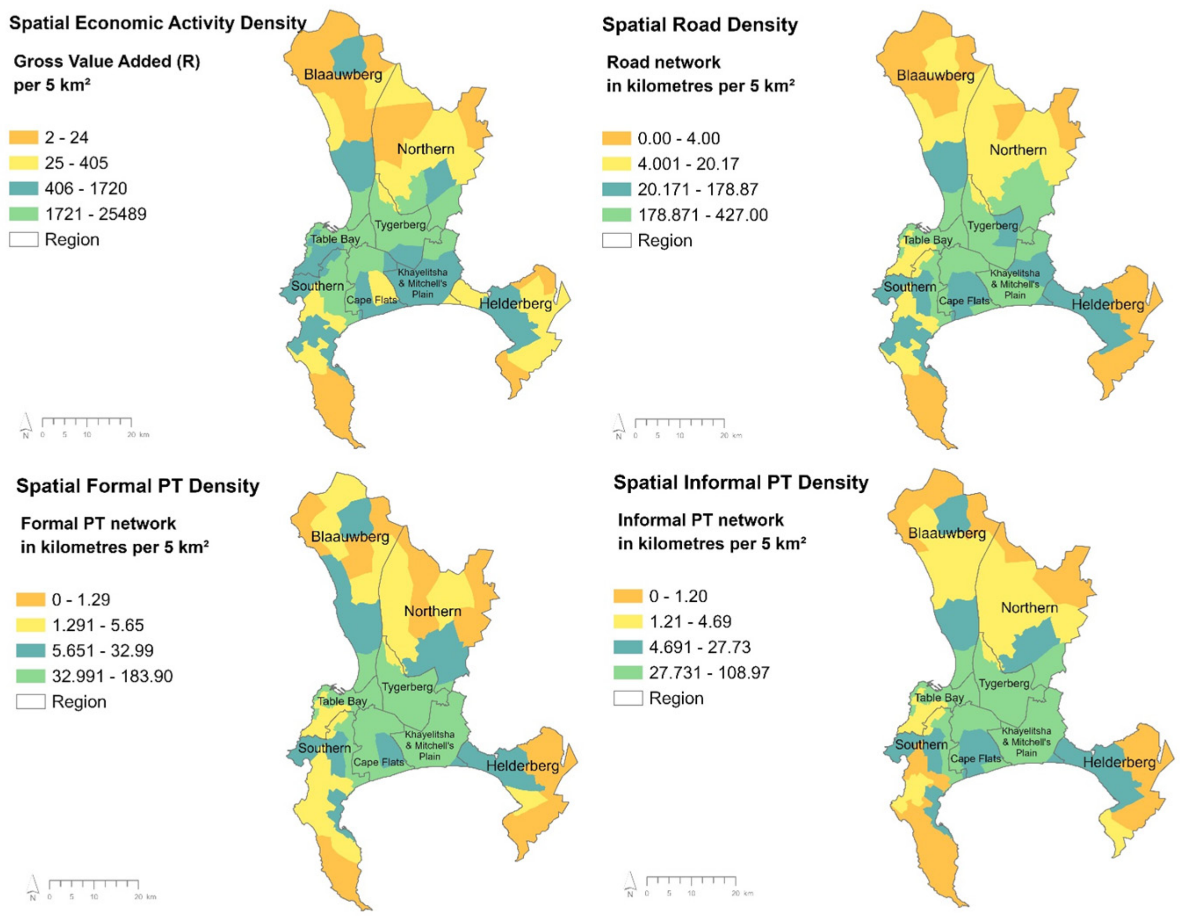

Figure 3: Spatial representation of economic activity and transport network length in Cape Town

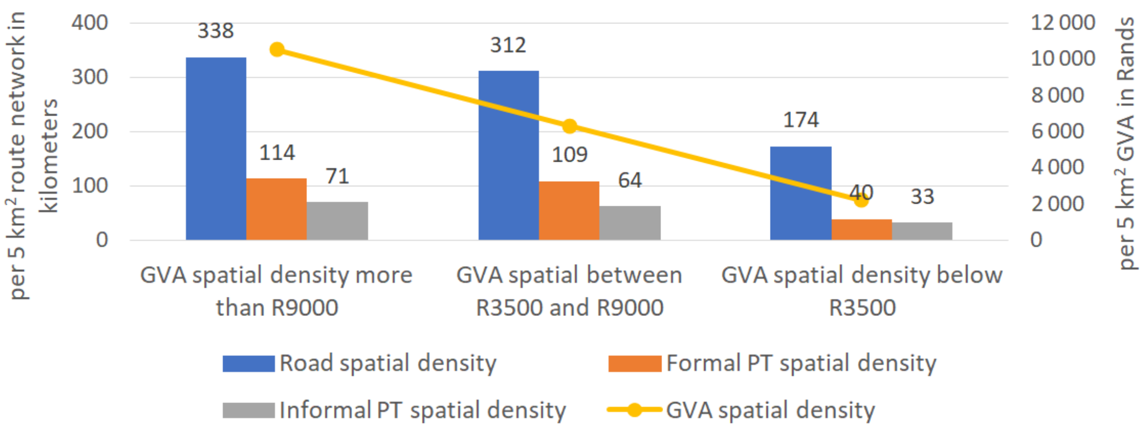

Figure 4: The association between economic activity density and transport network density for high, middle, and low economic activity areas in Cape Town

Figure 4 indicates that spatial transport network density varies by level of spatial economic activity density. The length of transport networks of roads, formal public transport, and informal public transport per 5 km^2 is high in highly economically active areas but decreases with GVA per 5 km^2 in middle and low economically active areas. For instance, the average spatial density of formal public transport varies from 40 km^2 in low economically active areas to 109 km^2 in middle economically active areas (plus 172%) to 114 km^2 in high economically active areas - the latter being 185% higher than in low economically active areas. Similar trends are observed for informal public transport and roads.

The results of Figures 3 and 4 suggest that the direction of the association between spatial economic activity density and spatial transport network density is positive instead of negative. However, correlation analysis is required to confirm this suspicion statistically.

4.2 Correlation Analysis

Table 1 contains correlation coefficients which indicate the direction, and size of this direction, for the association between transport network length and economic activity, per transport network type. Since the correlation coefficients are not between -1 and .00, they imply a positive association. Since the correlation coefficients are between 0.50 and +1, they imply a moderate to strong positive association. At p-level <.05, statistical significance is implied. Without implying causality, the correlation analysis shows that the length of transport networks and economic activity are closely associated – as the one increases, the other one does as well.

Table 1: Correlation coefficients for economic activity and transport network length per transport network in Cape Town

Transport network type		**Observations** mesozones	**Correlation coefficient** economic activity<>network length
Road		58	0.953
Informal public transport	Minibus taxi	58	0.910
Formal public transport	Golden Arrow Bus Services (GABS)	58	0.877
	MyCiTi	58	0.547
	Metrorail	58	0.527
Road: All metropolitan municipalities		405	0.900
Road: South Africa		25 048	0.662

The size of the association differs per transport network type. The association between length of transport network and economic activity is the strongest for roads and the weakest for rail. More specifically, the order from strongest to weakest, as it applies to Cape Town, is roads (0.953) followed by minibus taxi (0.910), GABS/government-subsidised scheduled bus services (0.877), MyCiTi/bus rapid transit (0.547) and Metrorail/passenger rail (0.527). The association between length of road network and economic activity is slightly stronger in Cape Town (0.953) compared to other metropolitan municipalities/cities in South Africa (0.900). Furthermore, this association is much stronger in Cape Town (0.953) compared to all other areas in South Africa (0.662).

The correlation analysis results in Table 1 confirms the suspicion raised by the spatial analysis results of Figures 3 and 4 that a moderate to strong statistically significant positive association between economic activity and transport network length exists. Furthermore, since the strength of the association differs per transport network type, Table 2 suggests that the economic activity associated with each kilometre of road, versus rail versus other forms of public transport differs. However, regression equations are required to confirm this suspicion statistically.

4.3 Regression Equations

Derived from scatterplots, regression equations can be used to make inferences about the association between transport network length and economic activity (Queiroz & Gautam, 1992). These equations assume some form of causality since economic activity is specified as the dependent variable.

4.3.1 Per Capita GVA Associated with Each Kilometre of a Transport Network

Equations 2 to 4 refer to the per capita GVA that exists for each kilometre of a transport network. In these equations, PGVA refers to per capita GVA, LR refers to length of roads, LFPT refers to length of formal public transport network and LIPT refers length of informal public transport network. The y-intercept terms of Equations 2 to 4 were excluded since these were not found to be significant at $p<0.05$.

Equation 2 can be interpreted as: There exists R4.04 of per capita GVA for each kilometre of road in Cape Town. The coefficient of 4.0435 is statistically significant ($p<0.001$), the number of degrees of freedom is 57 and the R squared value is 0.483. In other words, 48.30% of the variation in per capita GVA in Cape Town is explained by the variation in length of roads in Cape Town.

$$PGVA = 4.0435\ LR \tag{2}$$

To put Equation 2 to the test, one can compare the adjusted R squared value (0.483 or 48.30%) with the value derived from Equation 2a. In Equation 2a, LR refers to length of road in Cape Town in 2018, P refers to the population size of Cape Town in 2018 and GVA refers to GVA in Cape Town in 2018.

$$r2 = \frac{4.0435\ x\ LR}{PGVA} \tag{2a}$$

If values are inserted into the equation, the equation equates to 43.70%:[7]

$$43.70\% = \frac{4.0435\ x\ 11\ 696}{\frac{R443\ 304\ 000\ 000}{4\ 096\ 497}} \tag{2b}$$

Equation 2c's computed value should statistically equate to the R squared value of Equation 2, i.e. 48.30%. This is because the R squared value represents the variation in PGVA that is explained by the variation in LR. It is observed that the computed value of Equation 2c (i.e. 43.70%) is close to the R squared value of Equation 2 (i.e. 48.30%). This observation adds credibility to Equation 2.

The same method can be applied to formal and informal public transport. Equation 3 can be interpreted as: There exists R13.14 of per capita GVA for each kilometre of formal public transport in Cape Town. In this equation, formal public transport refers to passenger rail, bus rapid transit and formalised scheduled bus transport. The coefficient of 13.1391 is

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[7] Values were extracted from two sources: P and GVA from EasyData dataset by Quantec (2024). LR was obtained from the Comprehensive Integrated Transport Plan of the City of Cape Town 2018-2023 (TDA Cape Town, 2018).

statistically significant ($p<0.001$), the number of degrees of freedom is 57 and the adjusted R squared value is 0.223. The relatively high PGVA associated with LFPT (R13.14) compared to LR (R4.04) is likely since LFPT consists of three types of formal public transport[8]. Consequently, the equation should be interpreted as: there exists R13.14 of per capita GVA for each kilometre of GABS/government-subsidised scheduled bus services, plus each kilometre of MyCiTi/bus rapid transit, plus each kilometre of Metrorail/passenger rail. Totalling at 3 kilometres, instead of 1 kilometre, it is argued that: there exists, on the average, R4.38 (R13.14/3) per capita GVA for a total of 1 kilometre of GABS, MyCiTi and Metrorail.

$$PGVA = 13.1391\ PLFPT \tag{3}$$

Equation 4 can be interpreted as: There exists R2.79 of per capita GVA for each kilometre of informal public transport in Cape Town. In this equation, informal public transport refers to minibus taxi transport. The coefficient of 2.7887 is statistically significant ($p<0.01$), the degrees of freedom is 57 and the R squared value is 0.063. The relatively low R squared value of Equation 4 (0.063) compared to Equation 3 (0.223) and Equation 2 (0.483) suggests that the variation in per capita GVA is more so explained by the variation in the length of formal public transport and length of road compared to the length of informal public transport.

$$PGVA = 2.7887\ PLIPT \tag{4}$$

The regression equations presented in this sub-section reaffirms a moderate to strong positive association between economic activity and length of transport network. Furthermore, it affirms the suspicion raised in Table 2 that the economic activity associated with each kilometre of transport network length differs by transport network type. Of the three transport network types investigated, the most economic activity (PGVA) is associated with formal public transport (LFPT) followed by roads (LR) followed by informal public transport (LIPT).

4.3.2 Adequacy of Transport Network Length for Economic Activity Purposes

Varying degrees of length of transport network, population size and area size exist in the eight regions of Cape Town. Therefore, the association between economic activity and length of transport network differ not only by transport network type (as confirmed by Table 2 and Equations 2 to 4), but per region in Cape Town as well. Adequacy of length of transport network per region is derived based on transport network length and the association/ratio between it and economic activity. Queiroz and Gautam (1992) explain that transport network length is adequate to support economic activity when the ratio of economic activity to transport network length of an area is less than the coefficient of the regression equation of the larger area.

Table 2 contains the ratio of economic activity to transport network length, per transport network type, per region in Cape Town. It also contains the coefficient of the regression equation per transport network type in Cape Town. For example, in the Blaauwberg region, the ratio of its economic activity to its road network length is 3.03. This value is less than the coefficient of the regression equation of roads in Cape Town of 4.04 (see Equation 2). Consequently, adequate road network length exists in the Blaauwberg region to support economic activities in this region.

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[8]Aggregation of the three formal public transport types was necessary because the results are not statistically significant if each type of formal public transport is assessed separately.

Table 2: Adequacy of transport network length to support economic activity per region

Region	Obs	Road	Formal Public Transport	Informal Public Transport	Population density per km^2	Area size in km^2	GVA in R mil
		Ratio: EA to LR/LFPT/LIPT					
Blaauwberg	18	3.03	6.25	7.40	510	551	47 935
Cape Flats	10	14.67	48.53	167.13	4 524	159	81 510
Helderberg	10	12.86	54.32	1.94	747	324	30 580
Khayelitsha/ Mitchell's Plain	8	12.33	36.22	203.02	6 504	173	73 787
Northern	18	9.02	10.56	21.03	595	586	72 391
Southern	13	2.47	47.12	515.41	734	369	55 027
Table Bay	6	60.07	207.80	536.06	2 304	104	48 633
Tygerberg	11	29.51	90.40	491.44	5 169	168	86 825
Cape Town	94	4.04	13.14	2.79	1 683	2 433	496 691

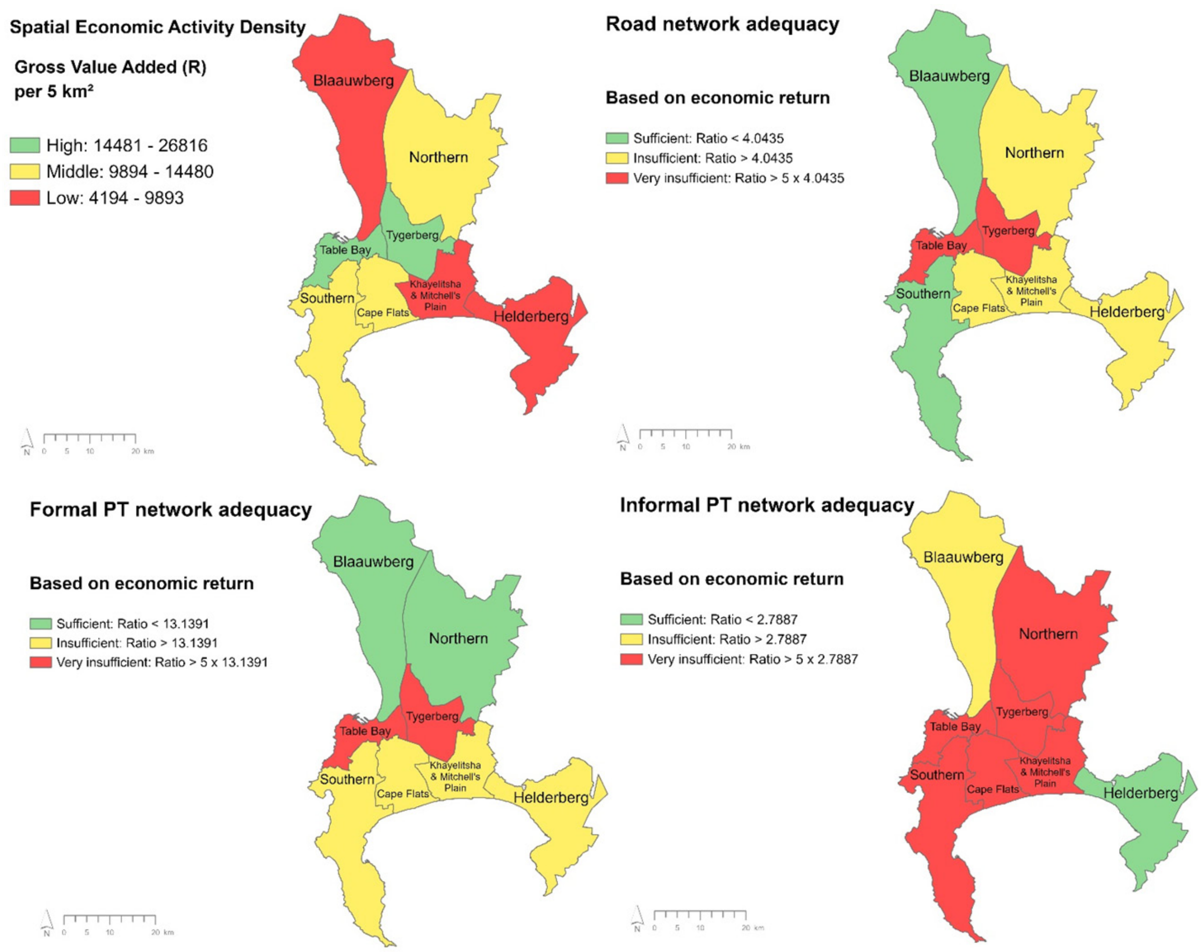

Figure 5: Adequacy of transport network length to support economic activity per region

Figure 5 consists of maps that depict the results of Table 2. It illustrates the adequacy of transport networks length to support economic activity per transport network type per region in Cape Town. Class intervals, as shown in the map legend, are classified by colour based on the region's ratio compared to the coefficient of the regression equation of the transport network type in Cape Town. The data and the unit of analysis is regional.

Figure 5 shows that the road network length in the Blaauwberg and Southern regions is adequate to support economic activity in these regions. Conversely, the road network length in the remaining six regions is inadequate to support these regions' economic activity. Of these six regions, the road network length is very inadequate in the two key economic activity regions of Cape Town, namely the Table Bay and Tygerberg regions.

Compared to roads, similar trends are observed for formal public transport. Two exceptions exist in that the length of the formal public transport network in the Northern region is adequate while it is inadequate in the Southern region. Conversely, Figure 5 indicates that the length of the informal public transport network is very inadequate in six of Cape Town's eight regions. It is to a lesser extent inadequate in the Blaauwberg region. One exception applies to the Helderberg region where the length of its informal public transport network is adequate to support the region's economic activity.

In conclusion, the adequacy of the overall transport network length (i.e. road, formal and informal public transport) is derived based on the deviation of a region's ratio from the coefficient of the regression equations. Based on the results of Table 2 and Figure 5, the adequacy of the overall transport network to support economic activity per region in Cape Town from best to worst is: Blaauwberg, Helderberg, Northern region, Khayelitsha/Mitchell's Plain, Cape Flats, Southern region, Tygerberg, Table Bay.

5. DISCUSSION

What is the association between the network length of different types of public transport and economic activity versus roads in the City of Cape Town? This is the research question that the results speak to, and that this discussion section will answer.

Spatial analysis raised the suspicion of a positive association between transport network length and economic activity, in terms of roads, formal and informal public transport (Figure 3). It also infers that this association is stronger in highly economically active areas, compared to middle and low economically active areas (Figure 4). This finding is similar compared to (Queiroz *et al.*, 1994; Matas *et al.*, 2018) (see section 2.1). The association difference is arguably attributed to exogenous factors such as attributes of an area's population. This argument is further explored in the remainder of this section.

Correlation analysis confirmed the suspected positive association between transport network length and economic activity as statistically significant at $p<0.05$. It also showed that the association differs per transport network type. This is because the correlation coefficients from high to low was ranked as: road, minibus taxi, GABS, MyCiTi, rail. This order is explained by three factors.

Firstly, minibus taxi, GABS and MyCiTi are road-based public transport services. Consequently, they utilise a part of the road network. In addition thereto, the length of these services[9] (6 083 km) is less than the network length of roads (11 696 km). Therefore, the association for roads will be stronger than that of the aforementioned road-

[9] The length the transport networks of minibus taxi (2517 km), GABS (3048 km) and MyCiTi (518 km) was derived from the shapefiles received from the City of Cape Town (see section 3.1). These lengths were validated by comparing it to that stated in the CITP 2018-2023 of the City of Cape Town.

based public transport services. Moreover, roads are used to transport both goods and people while public transport is used to transport only people.

Secondly, the association seems to be influenced by whether the transport service is government-owned versus privately-owned. The association between economic activity and MyCiTi and rail (both government owned) is much lower compared to minibus taxis (privately owned) and GABS (privately owned but government subsidised). Government owned and operated public transport often has a stronger social and political objective than an economic objective. For example, many cities are pro-poor and accordingly focus on improved accessibility of low-income areas. In fact, the majority of MyCiTi and rail routes serve these types of areas of which Khayelitsha/Mitchell's Plain, and the Cape Flats are examples of. Therefore, the association for government-owned public transport services is less than the association for the other transport network types investigated.

Thirdly, the impact of the deterioration of passenger rail (Metrorail) in Cape Town contributes to the relatively weaker association between rail network length and economic activity. This deterioration is linked to problems with rail infrastructure resulting in substantial decreased passenger rail journeys. In fact, by 2018, passenger rail journeys were 47% that of 2013. [10] Since 2018 (the reference year of this paper), passenger rail journeys decreased by 84% to just 41 759 journeys in the year 2023.

Regression equations confirmed that the association between transport network length and economic activity differs per transport network type. This is because regression equations showed that per capita GVA associated with roads versus formal public transport versus informal public transport differ. The coefficients of regression equations indicate that the most per capita economic activity associated with each kilometre of a transport network is formal public transport (up to R13.14), followed by roads (R4.04), followed by informal public transport (R2.79) (see Equations 2 to 4). This suggests that when economic activity is the main objective of transport network route expansion, that formal public transport should be the first priority, followed by roads, followed by informal public transport. In terms of formal public transport service type, network expansion should be in the order of GABS followed by MyCiTi followed by rail. This inference is based on the correlation coefficients (see section 4.2) since it was not possible to analyse regression equations per formal public transport service due to statistically insignificant regression equation coefficients at $p<0.05$.

Regression equations were also used to recommend government investment allocation to transport network length expansion within Cape Town (see Table 2 and Figure 5). By comparing the ratio of economic activity to the transport network length of a region within Cape Town to the coefficient of the regression equation of Cape Town, the adequacy of transport network length per region was determined. The results showed that the adequacy of the overall transport network to support economic activity, on the average, from best to worst is: Blaauwberg, Helderberg, Northern region, Khayelitsha/Mitchell's Plain, Cape Flats, Southern region, Tygerberg, Table Bay. For instance, it is inferred that funding be allocated more so to transport network length expansion projects in the Table Bay region instead of the Blaauwberg region.

Funding allocation insights per transport network type was also derived from the results. In terms of formal public transport, further investment in network length expansion need not

[10] Rail passenger journeys were derived from Land Transport Surveys of Statistics South Africa.

be in the Blaauwberg nor in the Northern region. The results show that formal public transport network length is adequate in these regions. This is arguably justified by the relatively low population density in these regions (see Table 2). In fact, of the eight regions, the Blaauwberg and the Northern regions has the lowest and second lowest of population density of the eight regions. Low population densities make formal public transport network expansion less viable. Conversely, formal public transport network length in the six other regions is inadequate to support economic activity. This is more so the case for the two regions of Table Bay and Tygerberg. Since 2018, funds in the billions of Rands, have been budgeted to expand the formal public transport network, MyCiTi. Its network length is going to be expanded in the Table Bay region to the Cape Flats through the implementation of the Phase 2A service of MyCiTi (Urban Mobility Directorate, 2022). The results justify that this MyCiTi expansion is needed since the formal public transport network in these regions is inadequate to support economic activities in these regions.

Funding allocation insights in terms of the road network in each region was also derived from the results. The road network of six regions were found to be inadequate to support its economic activities. Conversely, the road network is adequate in the Blaauwberg and Southern regions. Since road network expansion is costly and raises environmental concerns, and since more PGVA is associated with formal public transport, it is recommended to first invest in public transport (either formal or informal) before constructing more roads in Cape Town. The reasoning behind this also translates to the attraction of congestion in the long run when road network length expansion is prioritised over public transport service expansion. This is because temporary relief of congestion, due to more roads, will retain and attract private car users. Another reason for the expansion of public transport services on existing road networks is the geographical landscape in certain Cape Town regions that physically limits construction of addition road infrastructure. For example, although the Tygerberg region has a very inadequate road network to support economic activity, it has the longest road network length of all the regions. This, despite being the 3rd smallest region, and the 2nd most densely populated region. Consequently, regions like the Tygerberg region, limited by geographical constraints, should leverage its existing road network by expanding public transport services that functions on existing road infrastructure.

Of the three transport network types investigated, informal public transport is arguably the cheapest to expand. This is because the cost to expand minibus taxi services for government is linked to granting more operating licenses, which is relatively minimal. Informal public transport is inadequate in seven of the eight regions in Cape Town. Conversely, it is adequate in the Helderberg region as indicated in Table 2. However, informal public transport is inadequate in the following regions from most to least inadequate: Table Bay, Southern region, Tygerberg, Khayelitsha/Mitchell’s Plain, Cape Flats, Northern region, Blaauwberg. Consequently, it is recommended that government invest in demand analysis for the expansion of informal public transport services in these seven regions. Demand analysis is required to justify the release of additional operating licenses since additional operating licenses/minibus taxi operators can dilute the financial viability of routes.

6. CONCLUSIONS

This paper provided city-specific research of the association between transport network length and economic activity with an emphasis on public transport. Public transport is the main mode of transport in South Africa, yet the main transport-related concern of South Africans is public transport availability (Heyns & Luke, 2017; Statistics South Africa, 2021).

This paper provided economic justification for the expansion of transport networks, including public transport, since transport network length expansion is a means of increasing transport availability. More specifically, economic justification was provided for transport network length expansion, per transport network type and per region in Cape Town.

The results infer that more economic activity is associated with a kilometre of formal public transport compared to informal public transport. It also provides economic justification for the expansion of transport networks in certain regions within the metro. This includes economic justification for the expansion of the MyCiTi service to the Southern and Cape Flats regions of Cape Town via its anticipated Phase 2A service. The results can be used to inform budgetary decision making through planning and policy documents such as the City of Cape Town's Multi-Year Financial Operational Plan and Medium-Term Strategic Business Plan for Public Transport (MYFIN) and the draft National Public Transport Subsidy Policy of South Africa.

Transport is like the foundation of a building that supports economic activity. However, the South African context should be considered. Perkins et al. (2005) found a unidirectional relationship from economic growth to transport network length in South Africa, instead of a bidirectional relationship (see section 2.3). While causality testing was out of scope for this research paper, its results seem to support Perkins' finding. For instance, despite high levels of spatial transport network density in the low-income and highly populated regions of Khayelitsha/Mitchell's Plain and the Cape Flats, these regions are not as economically active compared to more affluent areas with similarly high levels of spatial transport network density. Furthermore, South Africa has the 10th largest road network in the world (National Treasury, 2021), while it simultaneously has the highest unemployment rate in the world since 2021 (World Bank, 2024).

While transport is the foundation of economic activity, people in 'building' that the 'foundation' (transport) supports must be able and willing to work. This sentiment relates to that of Wilfred Owen (1964): "Transport then, is a necessary but not a sufficient condition for economic development". Although extending transport network lengths will support economic activity, other solutions such as expanding educational, or job creation programs should be explored before or complementary to transport network length expansion. This recommendation is made especially in light of environmental concern over transport network length expansion.

Further research could attempt to affirm the causal link between transport network length and economic activity per transport network type at city-level in South Africa or elsewhere. Additionally, the validity of the use of regression equations to infer the adequacy of transport network length to support economic activity could be investigated in further research. Alternatively, a more complex model can be developed to measure adequacy of transport network length to support economic activity. This may include a triple-access approach.

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8. REFERENCES

Amairia, R & Amaira, B. 2017. Transport Infrastructure and Economic Growth : New Evidence from Tunisia an ARDL Bounds Testing Approach. *Journal of Infrastructure Development*. 9(2):98-112. Doi: 10.1177/0974930617732246.

Barro, R & Sala-i-Martin, X. 2004. *One-sector models of endogenous growth*. 2nd ed. New York: McGraw-Hill. Available at: https://mitpress.mit.edu/9780262025539/economic-growth/.

Bougheas, S, Demetraides, P & Mamuneas, T. 2000. Infrastructure, specialization, and economic growth. *Canadian Journal of Economics,* 33(2):506-522. Available at: https://onlinelibrary.wiley.com/doi/epdf/10.1111/0008-4085.00026.

Cheteni, P. 2013. Transport infrastructure investment and transport sector productivity on economic growth in South Africa (1975-2011). *Mediterranean Journal of Social Sciences,* 4(13):761-772. Doi: 10.5901/mjss.2013.v4n13p761.

CSIR. 2016. *Spatial Temporal Evidence for Planning South Africa*. Available: at: http://stepsa.org/socio_econ.html. Accessed 15 April 2024.

DBSA. 2024. *How the current state of public transport impacts employment in South Africa*. Available at:
https://www.dbsa.org/article/how-current-state-public-transport-impacts-employment-south-africa. Accessed 18 April 2024.

Farhadi, M. 2015. Transport infrastructure and long-run economic growth in OECD countries. *Transportation Research Part A*. 74:73-90. Doi: 10.1016/j.tra.2015.02.006.

Graham, DJ & Gibbons, S. 2019. Quantifying Wider Economic Impacts of agglomeration for transport appraisal: Existing evidence and future directions. *Economics of Transportation,* 19:100121. July 2018. Doi: 10.1016/j.ecotra.2019.100121.

Heyns, G & Luke, R. 2017. Importance of transport infrastructure for socio-economic development: A South African public opinion survey, in *4th International Conference on Development and Investment in Infrastructure - Strategies for Africa*, Livingstone. Available at:
https://www.researchgate.net/publication/319904070_Importance_of_transport_infrastructure_for_socio-economic_development_a_South_African_public_opinion_survey.

Hlotywa, A & Ndaguba, EA. 2017. Assessing the impact of road transport infrastructure investment on economic development in South Africa. *Journal of Transport and Supply Chain Management,* 11(0):0-12. Doi: 10.4102/jtscm.v11i0.324.

Karuri-Sebina, G. 2016. *State of South African Cities*. Johannesburg.

Koźlak, A. 2017. The Role of the Transport System in Stimulating Economic and Social Development. *Research Journal of The University Of Gdańsk,* 72(0):19-33. Doi: 10.5604/01.3001.0010.6873.

Kusideł, E & Górniak, J. 2012. Transport Availability vs. Development of Poland's Regions. *Central and Eastern Europe,* 15(4):105-116.

Matas, A, Raymond, JL & Ruiz, A. 2018. Regional infrastructure investment and efficiency. *Regional Studies*. 52(12):1684-1694. Doi: 10.1080/00343404.2018.1445845.

Melo, P, Graham, D, Levinson, D & Aarabi, S. 2017. Agglomeration, accessibility and productivity: Evidence for large metropolitan areas in the US. *SAGE Journals,* 54(1). Available at: https://doi.org/10.1177/0042098015624850.

Mohmand, YT, Wang, A & Saeed, A. 2017. The impact of transportation infrastructure on economic growth: empirical evidence from Pakistan. *Transportation Letters: the International Journal of Transportation Research,* 9(2):63-69.
Doi: 10.1080/19427867.2016.1165463.

National Treasury. 2021. *Provincial budgets and expenditure review: Chapter 7 - roads and transport*. Pretoria. Available at:
https://www.treasury.gov.za/publications/igfr/2021/prov/Chapter7-Roads-and-Transport.pdf.

NDoT. 2023. *National Land Transport Strategic Framework (2023 - 2028)*. Pretoria. Doi: 10.4324/9781351047722-1.

Njoh, A. 2000. Transportation infrastructure and economic development in Sub-Saharan Africa. *Public Works Management & Policy,* 4(4):286-296.

Owen, W. 1964. *Strategy for mobility*. Washington, D.C.: The Brookings Institution.

Palei, T. 2015. Assessing the Impact of Infrastructure on Economic Growth and Global Competitiveness. *Procedia Economics and Finance*. 23:168-175. October 2014. Doi: 10.1016/s2212-5671(15)00322-6.

Perkins, P, Fedderke, J & Luiz, J. 2005. An analysis of economic infrastructure investment in South Africa. *South African Journal of Economics,* 73(2):211-228. Doi: 10.1111/j.1813-6982.2005.00014.x.

Quantec. 2024. *Datasets sourced from Quantec EasyData*. Available: at: https://www.quantec.co.za/easydata/. Accessed 26 March 2024.

Queiroz, C & Gautam, S. 1992. *Road Infrastructure and Economic Development: Some Diagnostic Indicators*. (WPS 921). Washington, D.C. Available at:
http://documents.vsemirnyjbank.org/curated/ru/383071468739248249/pdf/multi-page.pdf.

Queiroz, C, Haas, R & Cai, Y. 1994. National Economic Development and Prosperity Related to Paved Road Infrastructure. *Tranportation Research Record*. (1455):147-152. Available at: http://onlinepubs.trb.org/Onlinepubs/trr/1994/1455/1455-019.pdf.

Statistics South Africa. 2021. *2020 National Household Travel Survey 2020 - Statistical release P0320*. Pretoria. Available at:
https://www.statssa.gov.za/publications/P0320/P03202020.pdf.

Tabachnick, B & Fidel, L. 2013. Review of Univariate and Bivariate Statistics, in *Using multivariate statistics*, 6th ed., Pearson Education Inc. 55-56. Available at: https://books.google.co.za/books/about/Using_Multivariate_Statistics.html?id=ucj1ygAACAAJ&redir_esc=y.

TDA Cape Town. 2018. *Comprehensive Integrated Transport Plan 2018 - 2023*. Cape Town. Available at: https://resource.capetown.gov.za/documentcentre/Documents/City strategies, plans and frameworks/Comprehensive Integrated Transport Plan.pdf.

Urban Mobility Directorate. 2022. *MyCiTi Phase 2A Industry Transition Business Plan 2022*. Cape Town. Available at:
https://www.capetown.gov.za/councilonline/_layouts/OpenDocument/OpenDocument.aspx?DocLocation=https://cityapps.capetown.gov.za/sites/CouncillorsOnline/MeetingDetails/TRNS/Reports/23/TRNS07060521-MYCITI PHASE 2A INDUSTRY TRANSITION BUSINESS PLAN ETC.pdf.

Weisbrod, G & Reno, A. 2009. *Economic impact of public transport investment*. Available: https://onlinepubs.trb.org/onlinepubs/tcrp/docs/TCRPJ-11Task7-FR.pdf.

World Bank. 2024. *Unemployment, total (% of total labor force)*. Available at: https://data.worldbank.org/indicator/SL.UEM.TOTL.ZS?end=2023&most_recent_value_desc=true&start=1991. Accessed 4 April 2024.

Zhang, Y & Cheng, L. 2023. The role of transport infrastructure in economic growth: Empirical evidence in the UK. *Transport Policy,* 133:223-233. January.
Doi: 10.1016/j.tranpol.2023.01.017.