A PROVINCIAL COMPARISON OF COMMERCIAL VEHICLE MOVEMENT

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ABSTRACT

Commercial vehicles may only represent a small fraction of all road users, but they contribute disproportionately to both congestion and wear of network infrastructure. Yet they are very often treated inadequately as mere noise in state-of-practice transport modelling endeavours. To address the underreporting of freight, this paper provides a novel analysis and comparison of the movement of commercial vehicles in South Africa. The analysis is based on the GPS logs of more than 30,000 vehicles that have been gathered over a 6-month period. The paper reviews the methodology used to extract useful activity chains from the GPS logs, and then proceeds to compare key vehicle and activity chain characteristics on a provincial basis. The characteristics include detailed spatial and temporal description of activity starts; number of activities per chain; chain duration; and the impact of commercial activities on the population distribution. Two novel metrics are proposed that are useful for local and provincial government to evaluate the effective use of its road infrastructure.

1 INTRODUCTION

Although private car users and drivers find themselves often annoyed with sharing the road space with slow-moving heavy vehicles, we all want the convenience of closely located shopping and leisure facilities: the majority of them reliant on being serviced by freight and other commercial vehicles.

Efficient movement of freight is critical to economic vitality. Fedderke and Bogetic (2009) show, specifically in the South African environment, that there is a statistical significant, positive, and often economical very strong relationship between road infrastructural measures and labour productivity. But little is known about where freight moves, and what is moved. Government must make decisions in terms of its core infrastructure investment, of which road infrastructure forms a main part, yet there is little decision support for them regarding freight and logistics.

This paper contributes in three ways. It firstly reports a novel methodology to extract the activity locations of commercial vehicles at a disaggregate level. This is valuable in giving a definitive answer to the question of where freight moves, without compromising the privacy of the vehicles. The methodology is employed to extract key characteristics about the activity chains of more than 30,000 commercial vehicles that were tracked over six months. Secondly, two metrics are reported and discussed in terms of measuring the productive use of road infrastructure. These measures are useful in assisting local and provincial government to evaluate their spending on road infrastructure. Thirdly, a provincial comparison is done between Gauteng, KwaZulu-Natal and the Western Cape. We report on the temporal and spatial distribution of activities, as well as the activity chain characteristics.

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The paper is structured as follows: we start with casting this paper against existing literature and related work in Section 2. Section 3 describes the process of activity inference. In Section 4 the new metrics are described, and the results of the provincial comparison are reported. The paper is concluded with a brief research agenda.

2 RELATED WORK

As commuters have activity chains such as home → work → leisure → home, a commercial vehicle typically also leaves a depot (home) location, conduct a number of activities—such as collection, deliveries or service calls—at different locations before returning to its home location. The majority of freight models, such as those reviewed by Ambrosini and Routhier (2004), are based on adaptations to the traditional four-step model: an aggregate approach that lacks the ability to track the individual stakeholder's (vehicle or firm) behaviour. Studying the disaggregate activity chains is hence absent in these models. Only recently did Friedrich et al. (2007) report on models where activity chain generation is considered.

This paper is largely based on the foundation laid by Joubert and Axhausen (2010) regarding activity extraction from Global Positioning System (GPS) data. In their paper, they review the current state of art in modelling urban freight movement. DigiCore Fleet Management made a data set, acquired through its Ctrack system, available for research and analysis. The data set contains the GPS logs for more than 30,000 commercial vehicles over a six-month period in 2008.

In the next section we review the process used to extract vehicle activities from the raw GPS data.

3 METHODOLOGY

Ignition-related triggers reported in the GPS data were used to identify activity start (vehicle off) and activity end (vehicle start) times. A thorough analysis by Joubert and Axhausen (2010) on activity durations suggests that 300 minutes are considered a good threshold to distinguish between major and minor activities. Major activities indicate the start and end-points of the activity chains, very much like home being the start and end-point of a person's daily activity chain. Minor activities, on the other hand, are the links that make up the activity chain. In the absence of additional information we cannot further distinguish between the purpose of the minor activities, i.e. whether they are service-related, goods delivery, or goods collection.

GPS data entries were split into separate files: one for each vehicle. Each file was then reduced to a string of activity sequences, from which activity chains were then extracted. As explained in Joubert and Axhausen (2010):

> "Whenever a major activity was identified, a new activity chain was created, starting with the major activity. Subsequent minor activities were added sequentially until the next major activity was identified. Any two consecutive activities from the same cluster were merged, assuming the short activity represents a relocation of the vehicle at the same venue. All chains not starting and ending with a major activity was removed to ensure only complete chains were evaluated. Chains containing only two major activities were considered mere relocations, and since they made up a very small proportion of the activity chains, they were also removed."

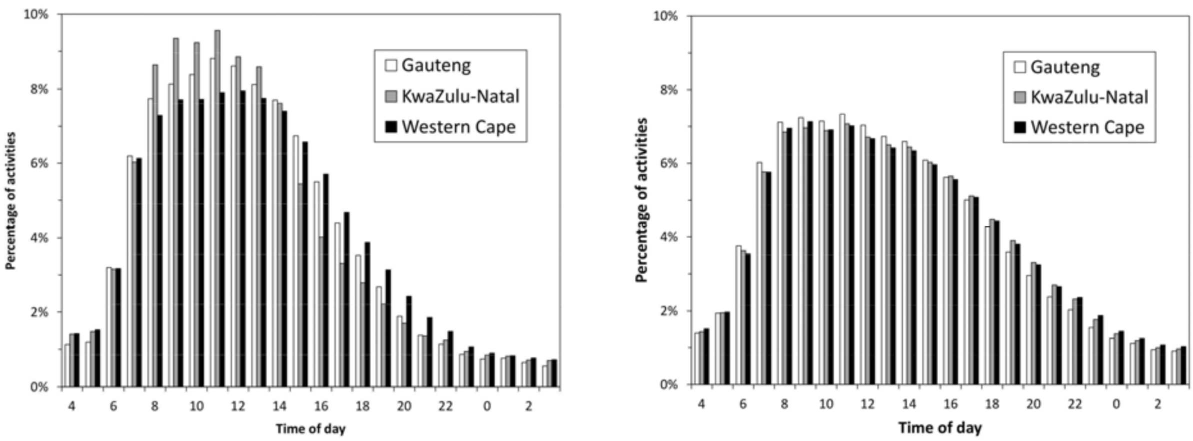
Vehicles were distinguished as being either a *within* vehicle for a specific area, spending at least 60% of its minor activities within that area or, alternatively, as a *through* vehicle. In a number of the comparative analyses in the next section, a distinction is made between within- and through traffic since they have distinctive characteristics.

4 COMPARATIVE RESULTS

For the results reported in this section, the methodology of Section 3 was applied to three areas with high commercial vehicle activity levels: Gauteng, KwaZulu-Natal, and the Western Cape. The objective is to investigate if the different study areas impact the vehicle activity and chain characteristics.

4.1 Activity and chain characteristics

The first analyses were concerned with activity chain characteristics, more specifically the time of day (hour) that the activities start, the number of activities per chain, and the average duration of the chains. The results from the analysis are presented in Figures 1 through 3.



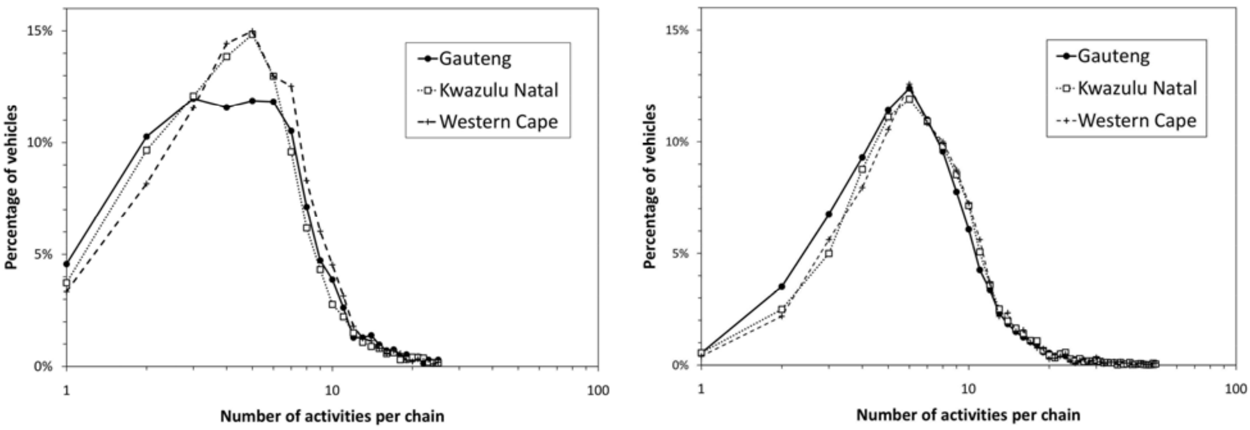
(a) Within area traffic. (b) Through area traffic.

Figure 1 - Minor activity start times (hour).

Activities from within vehicles (Figure 1a), although similar in shape, are more concentrated to start within the normal business hours (NBH) from 08h00–16h00, than the activities from through vehicles (Figure 1b). More specifically, in Gauteng, 69.7% of within vehicle activities start within the NBH as opposed to only 37.4% of through vehicle activities; in KwaZulu-Natal, 71.3% of within activities as opposed to 43.6% of through activities; and in Western Cape, 66.0% of within activities as opposed to 34.3% of through activities. In general, KwaZulu-Natal within activities are the most concentrated within business hours, indicated by high activity densities peaking at 11h00 and densities declining rapidly from 14h00. Western Cape, on the other hand, has a flatter activity density distribution for within vehicles suggesting intra-area movement of vehicles spread out later throughout the day.

The similarity among the three study areas for through traffic is easily explained: a vehicle considered as through vehicle in Gauteng perform less than 60% of its activities with Gauteng; and may perform activities in both KwaZulu-Natal and the Western Cape, as is often the case with long-haul trucks. The same vehicle will thus be considered a through vehicle in all three study areas, and its activity start times will be reflected accordingly in the statistics of all three study areas.

The number of activities per chain is reflected in Figure 2, with a distinction again between within vehicles (a) and through vehicles (b). The same argument as before holds for the similarity among the study areas for through traffic.

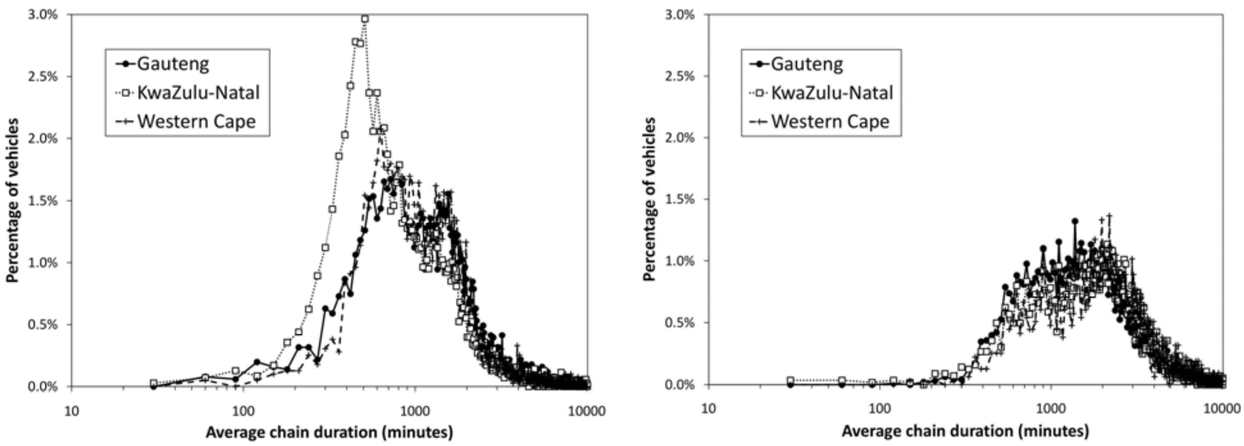


(a) Within area traffic. (b) Through area traffic.

Figure 2 – Number of minor activities per chain.

Gauteng vehicles, in general, have the fewest activities per chain (short chains), followed by KwaZulu-Natal and then Western Cape. One possible explanation is the level of congestion: high congestion levels in Gauteng may necessitate the use of smaller, more flexible vehicles resulting in more chains, each made up of fewer activities per chain.

Chain durations are reflected in Figure 3, with a distinction again between within vehicles (a) and through vehicles (b). The chain durations of within vehicles in KwaZulu-Natal are clearly shorter than those in the other two areas. The reader's attention is drawn to the log-scale on the duration-axis: suggesting that the spread of chain durations is strongly right-tailed. This is of interest as it serves as a potential proxy for the fleet utilisation: activity chains are terminated when an activity exceeding 300 minutes (5 hours) occur. In Gauteng, 36.1% of within vehicle activity chains are 18 hours or less (reflecting a possible two-shift operation); in Western Cape the figure rises to 38.14%; and in KwaZulu-Natal to 50.5%. This may be confirmation for the high logistics cost reported in the State of Logistics report (Ittmann et al., 2008).



(a) Within area traffic (b) Through area traffic

Figure 3 – Chain duration.

Spatial and temporal distribution

Since activities are extracted from raw GPS data, one can easily aggregate the activities to any level for reporting without compromising privacy concerns of individual vehicles. In this regard we value the mesoframe demarcation of the Council for Scientific and Industrial Research's Geospatial Analysis Platform (GAP) (CSIR Built Environment, 2009; Naudé et al., 2007). The equal-area demarcation is very useful to accurately highlight geographic areas of interest.

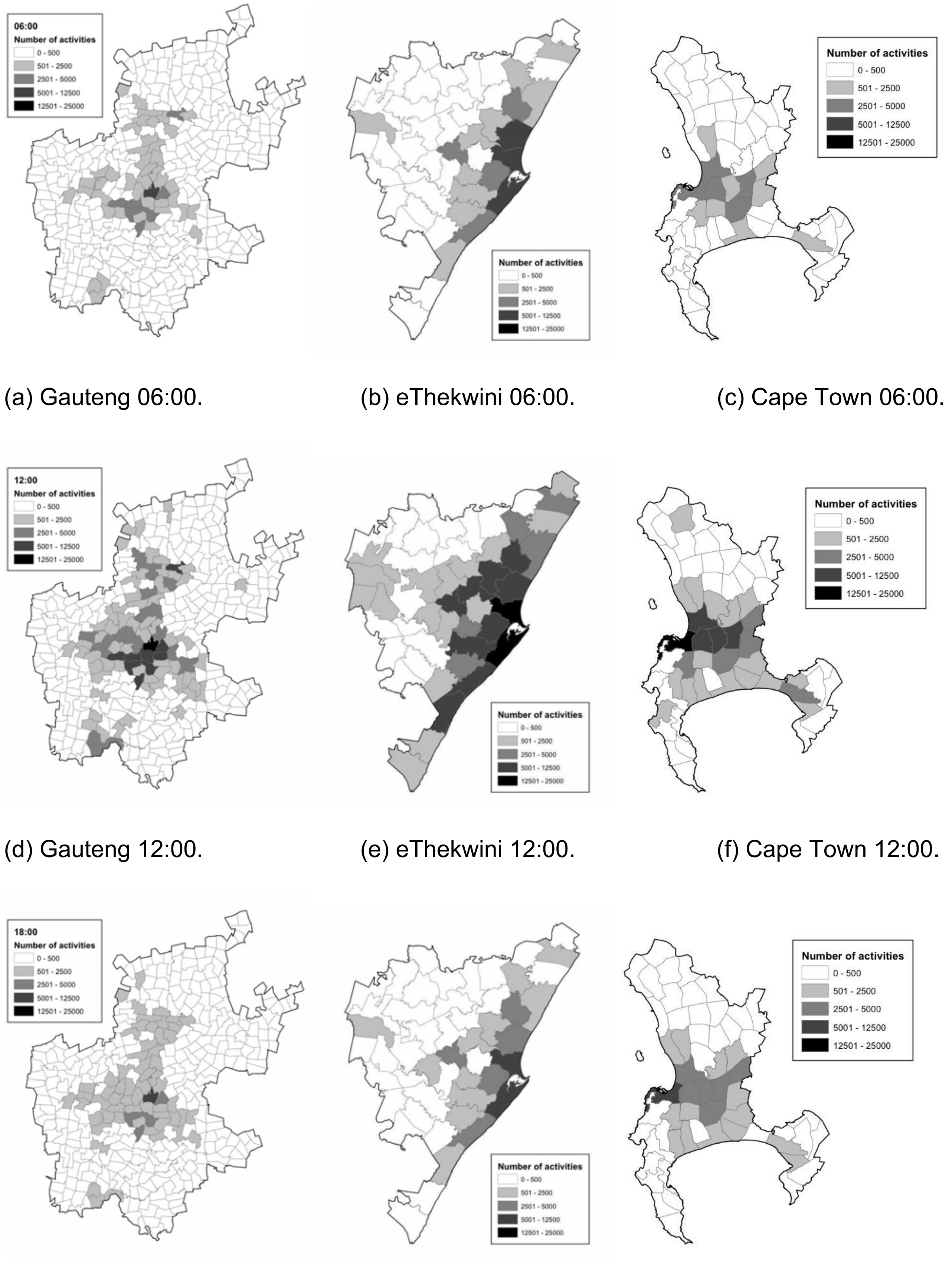
In the example reported in Figure 4 the activity densities for three hours of the day are shown, namely 06h00, 12h00 and 18h00. In the case of KwaZulu-Natal we choose to only report on eThekwini, and in the case of the Western case we report on only the City of Cape Town. The reason for the limited view is merely the large extent of the entire provinces where very low activity densities are found, contributing little towards our understanding of commercial activities.

In each figure, the number of activities reflects the number of activities that started during that specific hour. As noted by Joubert and Axhausen (2010) in the detailed study of activity distribution in Gauteng, there is a large overlap of commercial activity density with population density, highlighting the competition for urban space between the stakeholder groups. More detailed maps have been omitted from this paper due to length restrictions, but will be elaborated upon during the presentation.

Of interest in Figure 4 is that the location of activity densities do not change throughout the day, but only intensifies towards the late morning and early afternoons. The analysis is useful to identify not just the extent and characteristics of activities, but also more detailed spatial and temporal dynamics that may affect overall congestion.

4.2 Productivity measure

The premise in this subsection is that each commercial activity contributes, directly or in-directly, to the financial well-being and profitability of the firm. This, in turn, contributes to the economic well-being of the area. One fiscal metric then, as suggested in Joubert and Axhausen (2010), is to determine the amount of Gross Domestic Product (GDP) generated by the province for each commercial activity that was conducted within that province. Again, this metric is only made possible since we are able to extract disaggregate activity densities. The higher the metric value for a province, the more productive (or profitable) the province is in hosting commercial activities. In the analysis Gauteng is the most profitable with R 151,700 per activity; followed by Western Cape with R 106,200 activity; and then KwaZulu-Natal with R73,100 per activity. This paper do not suggest, though, that

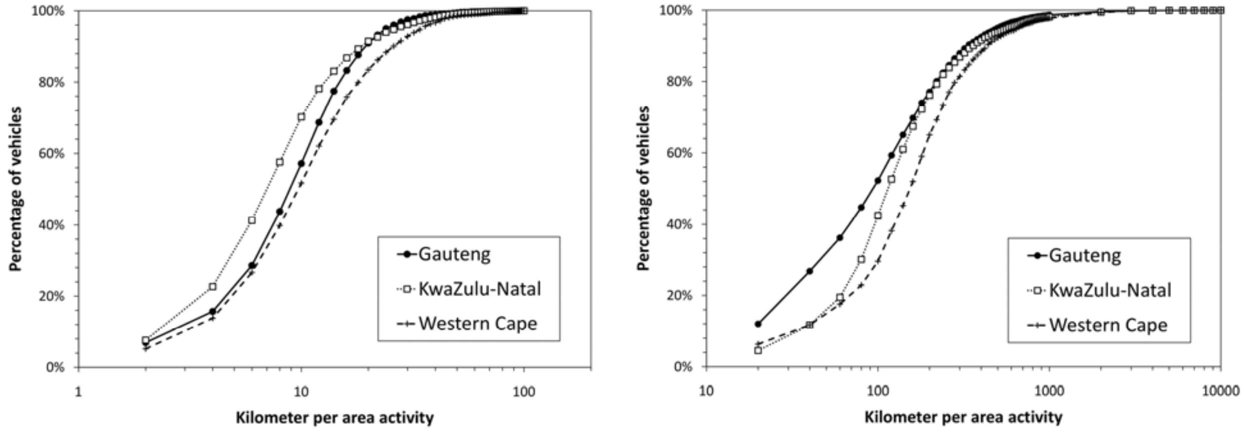


(a) Gauteng 06:00. (b) eThekwini 06:00. (c) Cape Town 06:00.

(d) Gauteng 12:00. (e) eThekwini 12:00. (f) Cape Town 12:00.

(g) Gauteng 18:00. (h) eThekwini 18:00. (i) Cape Town 18:00.

Figure 4 – Spatial-temporal analysis of activity densities.



(a) Within area traffic (b) Through area traffic

Figure 5 – Analysis of the kilometre-per-area-activity metric.

merely letting more trucks loose to road and occupy the road space will yield more productive provincial governments! But since individual firms drive fleet operations, one can plausibly argue that firms will ensure the profitable and controlled use of vehicles.

Government, however, is the supplier and maintainer of the road infrastructure as part of its core infrastructure offering that allows firms to conduct its business profitably. Here Joubert and Axhausen (2010) extended the first metric to calculate the number of kilometres travelled in the activity chain for each activity that was conducted in the study area. A low metric is preferable, indicating few kilometres travelled (use of road infrastructure) for each activity conducted (GDP generated from activity). Figure 5 reports the results, again distinguishing between within vehicles in (a) and through vehicles in (b). The cumulative density functions for within vehicles (Figure 5a) indicate as KwaZulu-Natal being the most productive of the three provinces, followed by Gauteng and then Western Cape. For through vehicles (Figure 5b) Gauteng is the most productive. With its omni-directional through traffic, one may be tempted to think that Gauteng, the smallest province occupying less than 2% of the land surface, will be least productive in terms of through traffic. One possible explanation may be the hub-role that Gauteng plays: many vehicles conduct business through its activities in Gauteng before proceeding to the final destination.

One does intuitively expect that through traffic make more use of road infrastructure than within traffic. This is confirmed when considering and comparing the scales on the kilometre-per-area-activity axes of Figures 5a and 5b.

The proposed metrics may be deceiving if merely compared with one another. Yet, they may serve valuable as a benchmark to evaluate the development over time for a single study area. As an example, a provincial government may compare its metric performance over time as it evaluates the impact that certain policy instruments and incentives have on say the relocation of businesses, and the associated vehicle activities, towards the periphery of the urban areas.

5 CONCLUSION

In this paper we reviewed the methodology put forward by Joubert and Axhausen (2010), and applied it to three provinces in order to evaluate and compare the differences in commercial vehicle activity and activity chain characteristics.

Although very similar, there do seem to be slight difference in terms of the activity start times, the number of activities per chain, and the chain durations among the three study areas. This, in turn, should suggest to policy makers that national interventions and nation-wide policy implementation should be carefully considered so as to not spur growth and development in one area at the expense of another.

Further refinement of the fiscal and productivity metrics are suggested to ensure more accurate representation of the chain distances used in calculating the metric values.

The main thrust forward is to identify, from the disaggregate vehicle data, key stakeholders with whom to partner and collaborate in future. Collaborating with select individual firms will allow better understanding in terms of the activity purpose. This, in turn, will allow improved analyses to distinguish not only between within and through traffic, but also between collections, deliveries, combined, and service chains.

6 ACKNOWLEDGEMENTS

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