Inferring commercial vehicle activities in Gauteng

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People and organisations pursue their goals through participating in a variety of activities. Since the chosen activities are usually separated by space and time, some form of transport is implied, which typically requires network infrastructure such as roads, and vehicles such as cars, buses and trains. In areas where there is a limited network infrastructure for the number of vehicles, traffic congestion occurs.

Studies show that well-constructed road infrastructure, which makes up the largest category of "core" public infrastructure, decreases transport cost. In turn, lower transport cost allows companies to be more profitable. Freight and commercial services are key users of network infrastructure, and the efficient movement of freight is critical to economic vitality.

The purpose of a study conducted at the University of Pretoria was to present novel results and characteristics about transport geography in Gauteng, the economic centre of South Africa. The study aimed to introduce new metrics to evaluate a geographical area's economic productivity based on commercial activity. In this study, an activity is the loading, offloading or service activities freight vehicles perform, and not necessarily the routes they travel.

The study distinguished between vehicles that performed the majority of their activities in the study area (within-traffic) and those that performed their activities in larger geographical areas (through-traffic). Over a six-month period, the study collected the Global Positioning System (GPS) data of 31 053 commercial vehicles through on-board fleet management tracking devices.

The choice of Gauteng as the study area is useful, as it has some unique characteristics. Although it occupies less than 2% of South Africa's land surface, it accounts for more than 30% of the country's gross domestic product (GDP). The province is also a porously bound economic space that acts as a gateway into the rest of southern Africa with omnidirectional through-traffic often originating from the two main ports in South Africa: Durban and Cape Town.

South African transport policy

In a paper presented at the 21st Annual South African Transport Conference in Pretoria, Stander and Pienaar (2002) reviewed the early South African permit system, which favoured government-owned railways and has restricted the carriage of goods by road since 1930. A gradual deregulation of freight towards free competition started in 1977 and concluded in 1989. The substantial increase in road freight haulage since the economic deregulation was only governed by the technical and safety regulation of operators and vehicles. In essence, government lost control of where freight moved, and to a large extent, of what was being moved.

In the past, the freight system was configured to support the movement of the products of inward industrialisation and provided cheap transport to a very limited number of economic participants, most of which were government-owned and -regulated (Fourie, 2001). The system was characterised by uneven flows of goods, and had dramatic peaks in specific areas. The Department of Transport implemented a project called Moving South Africa to address the challenges of the transport sector in 1999. The project outlines the strategic framework for the South African transport sector up to 2020. It addresses urban, rural, freight and special transport needs, analyses the sustainability of the present transport system, and presents possible solutions to the problems the industry faces.

Extracting activities from GPS data

DigiCore Fleet Management, which offers vehicle tracking and fleet management services, made its Ctrack system data available for the purposes of this study.

The detailed GPS log of commercial vehicles from 1 January 2008 to 30 June 2008 was recorded during the study. A total of 31 053 vehicles were identified, which represent approximately 1.5% of the national heavy and light delivery vehicle population. The vehicles represented in the GPS data are from customers subscribing to DigiCore's vehicle tracking and fleet management services.

In this study, ignition triggers were used to identify activity start and stop times. The start of an activity was identified as the point when an ignition is turned off, and an activity stops when the ignition is turned on again. Figure 1 shows the duration of all activities before chains of activity were identified. There are no clear breaks in the histogram, suggesting a definite, logical distinction between minor activities that make up the links of the activity chains and major activities that signal the start and end of an activity chain. The total number of activities exceeded 10.5 million. Although 31 053 vehicles represent a sizable sample, only the density of commercial vehicle activities could be estimated. This was achieved through kernel density estimation. The density maps of the minor and major activities are very similar.

An interesting observation was the near-continuous activity along the major route connecting Gauteng to Cape Town via Bloemfontein, as well as along the route from Gauteng to Durban (Figure 2). There is limited development along the majority of these routes, especially between Bloemfontein and Cape Town.

Activity and chain characteristics

The first analysis of the GPS data aimed to distinguish between through-traffic vehicles and within-traffic vehicles. Through-traffic vehicles perform activities in more than one geographical area, while within-traffic vehicles perform activities in one specific geographical area.

The 60% of vehicles that are considered through-traffic in Gauteng is considerably higher than the 6% reported by Hunt and Stefan (2007), who also conducted a study of the modelling of freight transportation and distribution systems in Calgary, Canada. This difference is attributed to the fact that Gauteng is a gateway into southern Africa. On average, 97% of the vehicles were active in Gauteng.

The time-of-day analysis of activities in South Africa confirms the survey results of Hunt and Stefan that commercial activities take place throughout the business day and not necessarily during the morning

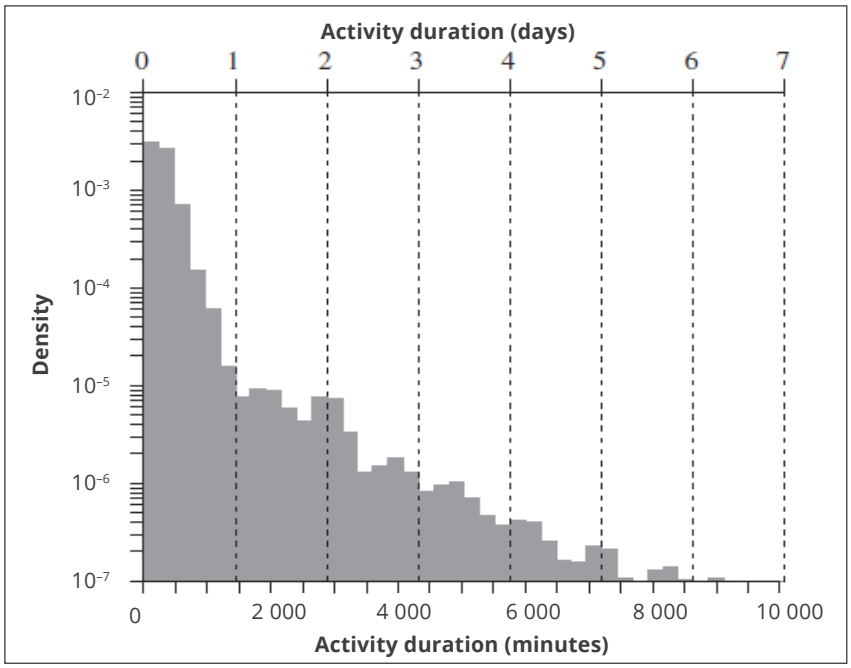

Figure 1: Histogram of all activity durations.

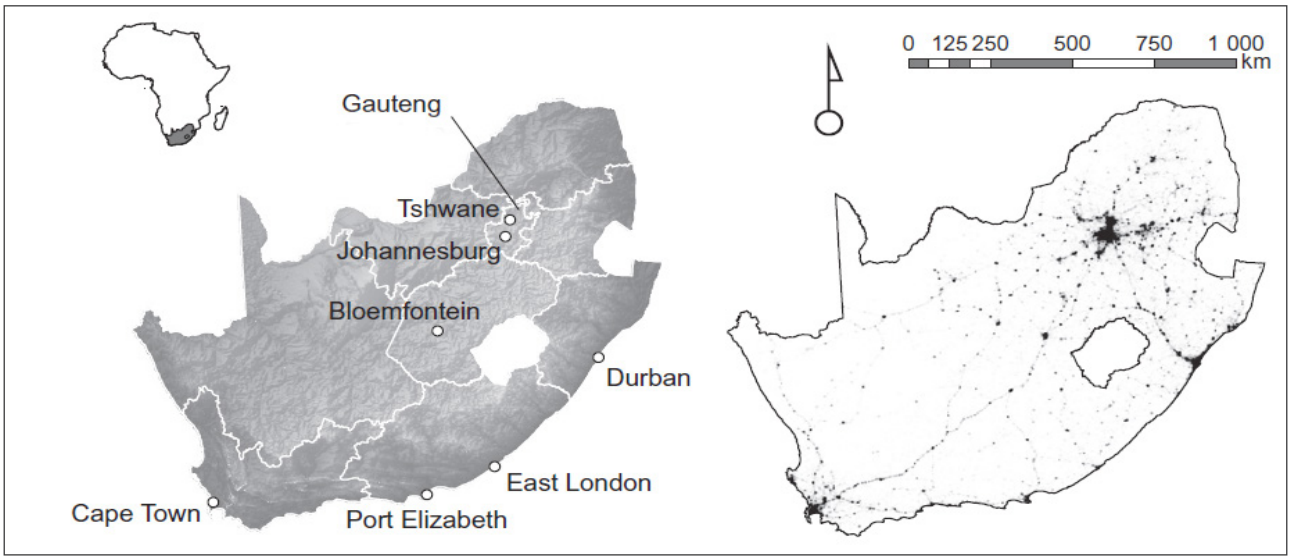

Figure 2: The extent and density of activities throughout South Africa, indicating Gauteng as the province of interest.

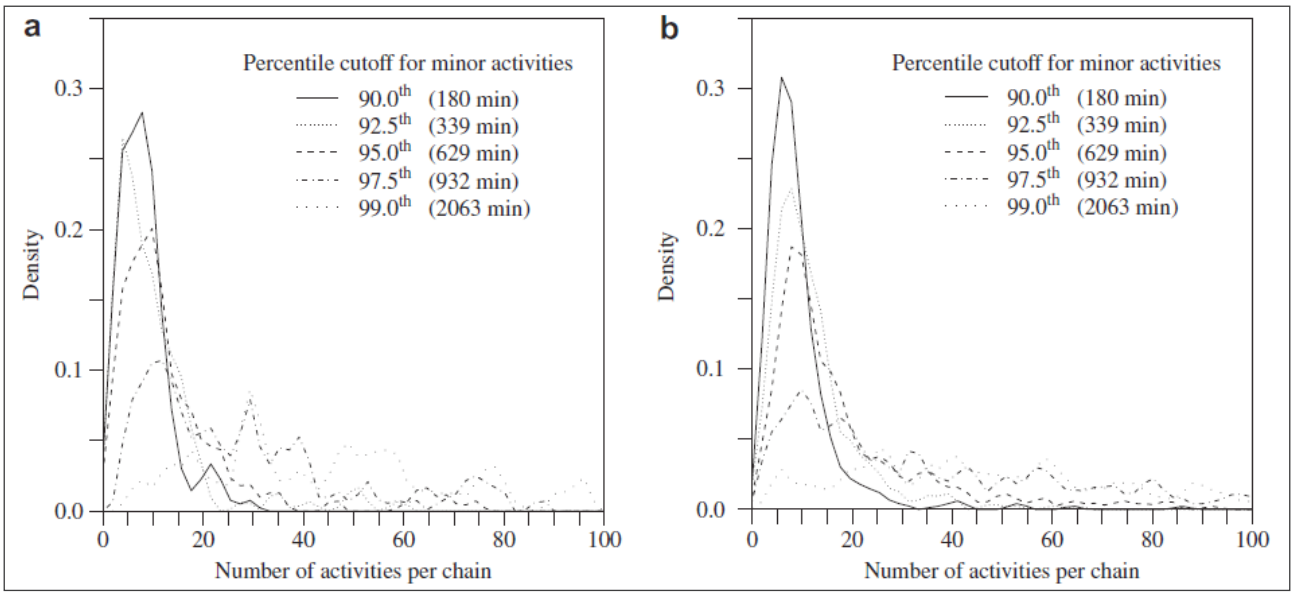

Figure 3: Comparison of the number of activities per chain for the different minor activity thresholds: (a) within-traffic and (b) through-traffic.

and afternoon peaks. Approximately 75% of all activities start between 08:00 and 17:00. The disaggregate description of commercial activities makes a significant contribution to understanding the spatial impact of commercial vehicles.

The number of activities per chain change with different minor activity threshold values was analysed. The comparison in Figure 3 distinguishes between within-traffic (Figure 3a) and through-traffic (Figure 3b). As expected, the higher the threshold value for both within- and through-vehicles, the more activities are included in each chain. The similarity of the distributions of the two vehicle types was not anticipated. It seemed plausible that within-vehicles would perform more activities during a business day than their through-traffic counterparts that are (typically) associated with long-haul trips where fewer, but larger deliveries per chain are concerned. On the contrary, the study shows that within-traffic has slightly fewer activities per chain.

Although the activity chain characteristics were much clearer at this point, the study attempted to find a way to link the spatial density of activities in Gauteng to productivity. Government funds the development and maintenance of transport infrastructure from taxes and levies. Fuel and road levies (tolling) also contribute to the development and maintenance of transport infrastructure. In return, people and companies need good transport infrastructure to competitively pursue their goals and be profitable.

In an article that refers to the richness and diversity of freight transport geography, Rodrigue (2006) notes that the transport and logistics corporations are generally more profitable than their (mostly) government-owned counterparts. Freight, being spatially more challenging and diverse than public transit, provides a means to measure the productive use of the infrastructure of a province.

Productivity metrics

The premise of the metrics that evaluate a geographical area's economic productivity based on commercial activity is that commercial vehicle activities contribute to the profitability of companies and to the GDP.

The first metric is fiscal and calculates the amount of GDP generated by the province with each activity conducted in the province. The higher the metric value, the more productive an area, contributing more to GDP per commercial vehicle activity. Gauteng makes the highest fiscal contribution at R151 700 per activity, followed by the Western Cape at R106 200 and KwaZulu-Natal at R73 100.

Another metric that could be used to determine the freight productivity of a province is distance per activity. For each vehicle, the total distance of chains that had one or more activities in Gauteng was divided by the total number of activities the vehicle performed in the province. The fewer kilometres travelled on the road per activity, the more spendable GDP could be invested in the development and maintenance of infrastructure. The results are visualised in Figure 4, which again distinguishes between within-traffic and through-traffic.

Within-traffic is more productive than through-traffic. As within-traffic performs the majority of its activities within the province, its use of the road infrastructure is much higher. The contribution is also higher with more activities and the combination results in a more productive use of the road infrastructure, and a lower metric value.

Since traffic congestion is notoriously unproductive, it is interesting to note that between 60 and 87% of chains have ended before the afternoon peak starts at 16:00. This further fuels the debate that commercial vehicles are lesser contributors to peak-hour congestion.

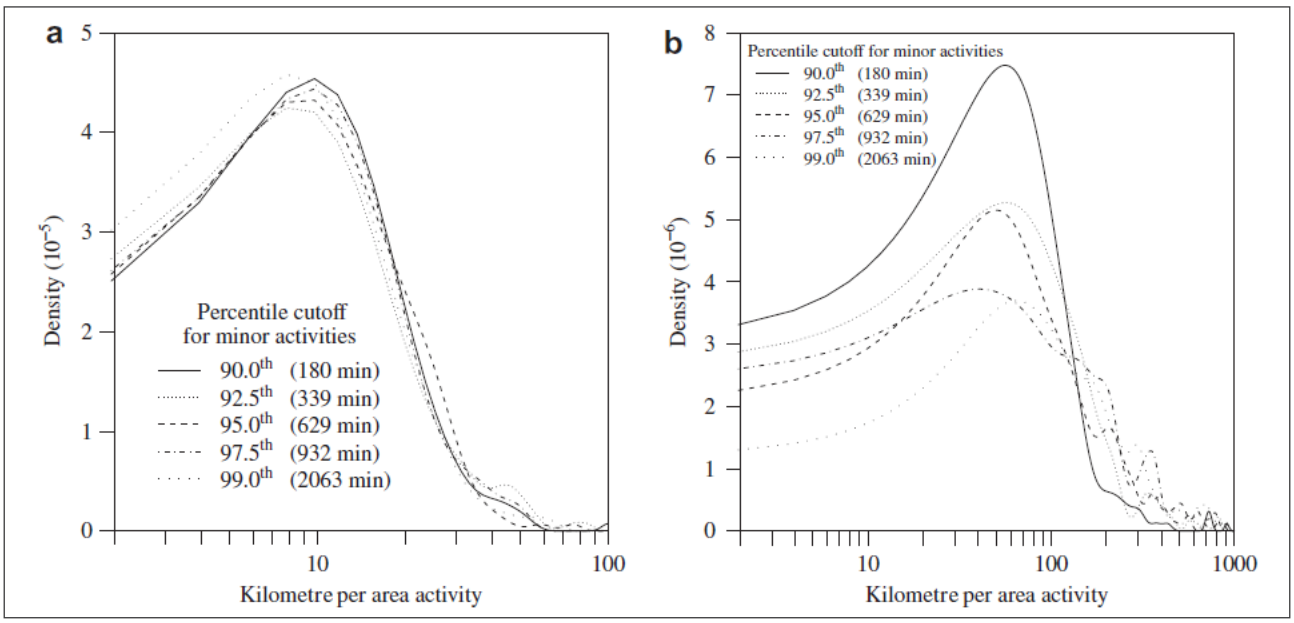

Figure 4: Comparison of the chain distance per activity metric for the different minor activity thresholds: (a) within-traffic and (b) through-traffic.

Density comparisons

There is a significant overlap between activity densities and population densities. In a paper published in *Journal of Transport Geography*, Hesse and Rodrigue (2004) observe that distribution centres are concentrated on the fringes of urban areas and beyond. In South Africa, logistic activities are concentrated in the urban areas, especially in Gauteng.

To be an effective economic hub and gateway into southern Africa, Gauteng should consider a strategic urban development plan. This plan should consider the activities and movement of both people and freight. As a result, the richness of the transport geography cannot be fully exploited with only the observed characteristics of commercial vehicles, for example, the number of activities per chain, the chain duration and the temporal distribution of activities. The interaction of commercial vehicles with their environment needs to be considered in an appropriate context.

Conclusion

Although Rodrigue (2006) praised the profitability of the freight transport sectors, such praises may be somewhat dampened if the work of Stander and Pienaar (2002, 2005), which notes that freight does not cover the full social and political cost for its road use, is considered. Knowing where business and freight stakeholders are located and what the interactivity distances are will allow researchers to evaluate and compare the activities against underlying land-use data in the future. In turn, land-use analysis may provide guidelines in predicting future freight activities based on strategic land-use master plans.

Using a large-scale agent-based transport simulator such as the Multi-agent Transport Simulation (MATSim) toolkit makes it possible to incorporate freight movement in dynamic traffic simulations.

References

Fourie, D. 2001. The restructuring of state-owned enterprises: South African initiatives. *Asian Journal of Public Administration* 23(2):205–216.

Hesse, M & Rodrigue, J. 2004. The transport geography of logistics and freight distribution. *Journal of Transport Geography* 12(3):171–184.

Hunt, J & Stefan, K. 2007. Tour-based microsimulation of urban commercial movements. *Transportation Research Part B: Methodological* 41(9):981–1013.

Rodrigue, J. 2006. Transport geography should follow the freight. *Journal of Transport Geography* 14(5):386–388.

Stander, H & Pienaar, W. 2002. Perspectives on freight movement by road and rail in South Africa. Paper presented at the 21st Annual South African Transport Conference, Pretoria, South Africa, 11–13 July.

Stander, H & Pienaar, W. 2005. Land freight issues in South Africa. Paper presented at the 24th Annual South African Transport Conference, Pretoria, South Africa, 11–13 July.

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