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Evaluating the efficiency of urban activity chains

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Abstract

Many city logistic initiatives are large in scale and aim to improve the efficiency and overall state of goods movement within our urban areas. Unfortunately the implementation and day-to-day operations of urban goods movement is less than optimal. Commercial vehicles have many activities in their activity chains, from when they start at a terminal depot, until they return. Some vehicles have as many as hundreds of activities in a single chain. Unfortunately many consecutive activities in a vehicle's chain occur at the same facility, suggesting that vehicles have to maneuver and relocate a few times before their true, economically useful function is completed. In this study we consider such duplicate activities and perform temporal and spatial analyses to better understand the nature of these productivity sinks.

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Keywords: Activity chains; efficiency; duplicate activities

1. Introduction

Although the state of practice in transport modelling still favours adaptions of the classical four-step model, much progress has been made in disaggregate activity-based and more recently also agent-based models (Arentze and Timmermans, 2005; Bhat et al., 2008; Vovsha and Bradley, 2006). In a special issue on the behavioural insights into the modelling of freight transportation, Hensher and Figliozzi (2007) acknowledge that freight models and related public policy tools have lagged behind logistics and technological advances. They also emphasise the need for transport models that are rich in behaviour and that are more realistic representations of the supply chain structures are are inherent in relationships among logistic stakeholders.

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Companies involved in urban and city logistics are often more advanced in their modus operandi than the transport planning models that are suppose to assist authorities to plan for city logistics infrastructure that should support those companies. One reason is that, from a planning perspective, we do not understand the activities and behaviour of the various freight agents.

In this paper we build on a growing body of knowledge aiming to improve our understanding of urban freight movement. More specifically, we study the body of knowledge that studies the activity chains of commercial vehicles. An *activity chain* is the sequence of activities that a commercial (possibly freight) vehicle performs, with the activities being geographically separated and connected by trips. Consequently, Sharman and Roorda (2011) refer to the activities as *trip ends*. They use a hierarchical clustering method to identify frequently-visited facilities from geospatial positioning system (GPS) records, and later study inter-arrival times and activity duration patterns in Sharman and Roorda (2013).

Joubert and Axhausen (2011) also extract activity chains from GPS records, and perform exploratory analysis on activity and activity chain durations, as well as time of day distributions. The paper also introduces a productivity metric that measures a fiscal value per commercial vehicle activity. The metric was subsequently considered by Sturm et al. (2014). Greaves and Figliozzi (2008) argue why it is useful to collect GPS data from freight vehicles and further process it to obtain travel and trip information. Their paper also address data collection issues experienced with working with GPS data.

From the data set of 40 000+ vehicles studied by Joubert and Axhausen (2011) it emerged that many consecutive activities actually occur at locations in very close proximity to one an- other. More often than not these were the *same* facilities. One explanation that this paper aims to study further is the frequent occurrence where logistics vehicles queue outside distribution centres, waiting their turn to enter and offload their cargo. As they stand parked outside the gate waiting their turn, they would restart from time to time, move a couple of meters further, and then switch off again. Since many GPS extraction algorithms work on ignition signals, such short-distance relocations are actually identified as separate activities in the activity chains, even though they are non-value-adding.

The question this paper aims to answer is 'what are the spatial characteristics of locations where multiple consecutive activities in an activity chain occurs at the same location?'

The relevance to City Logistics is that inefficiencies in activity chains contribute to higher logistics cost, which in turn may negatively influence the evaluation of City Logistics initiatives like urban consolidation centres, after hour deliveries, and others as covered in Taniguchi and Thompson (2014). This paper makes a methodological contribution as it presents a diagnostic approach to identify areas for logistic efficiency improvement. The actual efficiency intervention, though, remain context specific. Instead of blanket improvement suggestions, this paper will show that one can identify concrete opportunities for 'easy-wins'.

The paper is structured as follows. The next section introduces the process of extracting activity chains, and presents the methodology for identifying pockets or areas of inefficiencies. Section 3 provides more detailed discussion of the actual results, and we conclude the paper in Section 4 with an outlook on future research opportunities.

2. Methods

The activity chains extracted by Joubert and Axhausen (2011) were subsequently clustered using a density-based clustering algorithm to identify the actual facilities (locations) where those activities take place (Joubert and Axhausen, 2013). Each activity was then associated with an actual facility, and not merely a GPS coordinate.

Our interest in this paper is identifying instances where consecutive activities in an activity occurred at the *same* facility. That is, two consecutive activities, each with the same facilityId. Even though the data covers the entire Southern Africa, the focus of this paper would be on the large urban megacity of the Greater Gauteng region, which include the Cities of Johannesburg, Tshwane (formerly Pretoria), and Ekurhuleni, and we will also look at the City of Cape Town.

In this paper, we will follow a similar approach as published in Joubert and Axhausen (2011, 2013) to extract activity chains from raw GPS data. An example of a vehicle's activity chain is shown in Fig. 1. For each vehicle, C1 in this case, we have one or more activity chains with different lengths, n. For each chain we know the number of activities, n, which includes the first and last terminal activity that represents *depot* or *home-base* activities. For each activity in the chain we know the start and end date and time, the coordinates, and the facility associated with the activity. As argued in Joubert and Axhausen (2013), it is useful to *not* have certain activities associated with