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Route choice behavior in a radial structured urban network: Do people choose the orbital or the route through the city center?

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ABSTRACT

We use a license plate survey to study route choice through the city center of a medium-sized Dutch city, in which car drivers can basically choose between the orbital and center ring. For a sample of 1397 trips, we fitted a multinomial logit regression model. According to this model, route choice is relatively little influenced by actual travel time. This corresponds with the fact that many drivers did not choose the shortest time route. Travel distance in combination with one "route type velocity" for all orbital routes, and one route type velocity for all center routes is the most decisive factor. The route type velocity indicates how fast and attractive routes of that type are (being perceived). The results support the hypothesis that orbital routes are more attractive as these routes avoid the busy city center. This effect is however partly offset by the fact that drivers also prefer routes in the direction of their destination. These direct routes are mainly center routes. The results show the importance of considering complete routes in relation to their location and not only as a set of links and nodes when modeling route choice.

1. Introduction

Car traffic causes severe livability problems in cities around the world. One of the main goals of (road) authorities is to minimize the distance traveled through vulnerable areas such as residential areas and recreational or historical city centers. To this end, orbitals (ring roads) have been constructed, especially throughout Europe, from highways around the biggest cities to orbital roads around city centers, villages, and residential areas.

One of the main challenges is to make the orbital attractive for through traffic, while keeping the city center accessible. This raises an important research question. Under which circumstances does through traffic use the orbital route if the city center route is a viable alternative? A hypothesis is that this mainly depends on two competing factors. Orbital routes may be preferred, because the busy and dense city center is less comfortable for driving, not in the last place due to the large amount of slow traffic. However, center routes may be preferred, because they form direct routes between opposite sides of the city center.

By framing the choice between center route and orbital in this way, we clearly make the corresponding route choice problem geographically in nature. Environmental or land use factors are favorable for orbital routes, while spatial (network) characteristics like distance or "directness" are favorable for center routes. In this paper, we will study the influence of these factors on route choice.

Real-world studies on the influence of environment on route choice are sparse. Numerous studies, starting more than fifty years ago, have shown that specific landmarks and network features are memorized as reference points or anchors (e.g., lynch, 1960; Carr and Schissler, 1969) and have explored how these anchors are structured (e.g., from large to small scales) in mental maps (e.g., Golledge et al., 1985; Couclesis et al., 1987). Some studies have built on these findings to explore the relation with route planning (e.g., Wiener and Mallot, 2003). However, most of these studies have been controlled experiments in simplified simulations with small samples. Recently some real-world studies have been carried out as geographical data can be more easily accessed (e.g., via Google Maps), and field experiments can be carried out with greater ease due to automatic sensing techniques (e.g., GPS). Manley et al. (2015) for example used a large sample of minicab drivers in London to show that spatial reference points indeed play an important role in route choice. Zhang and Levinson (2008) found perhaps not surprisingly that a route with a scenic environment was especially preferred by recreational travelers. In a different approach, Snizek et al. (2013) used Google Maps to assess which locations in Copenhagen were experienced as positive and negative by cyclists, and which attributes could be related to these experiences.

At the same time, road environment is also becoming a more important societal issue for (desirable) route planning. De Baets et al. (2014) found that in many instances the use of secondary roads can be reduced significantly if route planners would advise socially desired routes (using primary roads as much as possible), without this leading to significant detours. Ramaekers et al. (2013) also used different road categories in Flandres to study how these are used by travelers with

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different trip purposes. The influence of road category on route choice has actually been studied earlier in the US by Ramming (2002), Li (2004) and Zhu (2010) who found that travelers mainly prefer primary roads or freeways. The studies in Flandres, however, appear to go a bit further in the sense that road type is explicitly linked to the environment or intended purpose of the road rather than its physical characteristics.

Studies on the influence of spatial factors (of the network) on route choice are probably more extended than those regarding route environment. Although travel time was (and still is) often viewed as the most important discriminant in route choice, the role of spatial factors like "directness" and distance was recognized early on (e.g., Huchingson et al., 1977). More recently, GPS studies have confirmed that for specific trip purposes, e.g., commuting, travelers prefer shorter distance routes (e.g., Papinski et al., 2009; Zhang and Levinson, 2008). Moreover, according to GPS studies in the US (e.g., Jan et al., 2000; Zhu and Levinson, 2010) and a web-based survey in Italy (e.g., Prato and Bekhor, 2006) most travelers do not choose the shortest time route. In all three of these observational studies fewer than 50% of the travelers chose the shortest time route, while there was no clear preference for shortest time routes compared to shortest distance routes.

In traffic engineering related literature, route planning strategies are in general *graph-based*. The traveler is assumed to know the link connections between origin and destination and chooses the route that optimizes certain characteristic given the structure of the road network (graph). For example, the most direct route could be defined as the one in which the total number of turns is minimal (e.g., Turner and Dalton, 2005). This presumes knowledge about all the (possible) turns in the graph. However, from cognitive sciences there is also evidence that travelers use reference points (as mentioned earlier) or adopt *direction-based* strategies (e.g., Hölscher et al., 2011; Conroy Dalton, 2003). In such strategies, travelers keep on determining their position with respect to the destination, such as with dead reckoning (e.g., Sholl, 1988), and adapt their route accordingly, for example, by minimizing the angle between the route direction and the direction of the destination (least-angle strategy; e.g., Bailenson et al., 2000; Hochmair and Frank, 2000). Hochmair (2005) performed a case study to examine the effectiveness of the least-angle strategy in terms of travel distance and found that its effectiveness depends on the network structure.

In this paper, we study route choice for traversing the center of a city with a typical radial shaped network, extending the aforementioned work. The paper is structured as follows. In Section 2, we present our approach. In Section 3, we describe the survey data, and in Section 4, we select the routes in the route set. In Section 5, we present the sample and estimate travel times. In Section 6, we describe the route choice model, and in Section 7, we provide the most important results. In Section 8, we conclude with a discussion.

2. Approach

For this study, we select origin–destination (OD) pairs with origins and destinations on opposite sides of the city center. For these OD pairs, we evaluate actual route choices. As the inner center is car free, route choice boils down to a choice between the center ring and the orbital, both in clockwise and counterclockwise direction. The route set can thus be generated in a simple and straightforward way.

While complicated route set generation is not an issue, data gathering is more of a challenge. The most common techniques are stated preference, simulation or revealed preference. Stated preference (e.g., Khattak et al, 1993) and simulation (e.g., Mahmassani and Herman, 1990) are powerful techniques when studying specific aspects of choice behavior, but one can question whether these techniques are always able to mimic the real world with its many complexities. Revealed preference describes actual choice behavior, but has a drawback that the researcher can exert less control and focus during the choice experiment. Revealed and stated preference studies are therefore somewhat complementary, each with their own opportunities and challenges.

Like stated preference, revealed route choice studies have been carried out by questionnaires, like self-completion diaries (e.g., Mahmassani and Jou, 2000), web based surveys (e.g., Prato, 2005) or telephonic questionnaires (Vrtic et al., 2007). Increasingly, revealed route choice studies are being done with floating car data, e.g., GPS tracking (e.g., Jan et al., 2000; Papinski et al., 2009; Zhu and Levinson, 2010). GPS tracking is in some sense complementary to questionnaires. Information about the individual context is in general less detailed, but individuals can be followed over longer time periods, enabling researchers to study dynamic aspects of route choice behavior. In addition, the spatial resolution of observed route traces is basically high enough to identify single paths in the road network.

Questionnaires and GPS tracking both focus on individuals rather than specific trips. For our study, this is a drawback, as we have a particular interest in trips between opposite sides of the city center. As travelers in the sample may also travel between other OD pairs, samples of individuals need to be quite large to gather enough relevant trips. In the near future, GPS studies with large samples may become more common (e.g., Rieser-Schüssler et al., 2012), but in some countries, like the Netherlands, GPS samples for route choice studies remain relatively small, (partly) due to privacy restrictions and commercial interests.

Roadside observations such as license plate surveys can fill this gap. Such surveys have been used to study route choice in the past (e.g., Hamerslag, 1981), but only to a limited extent. This is unfortunate, because extended license plate surveys have been carried out in several medium-sized municipalities. A license plate survey usually does not yield information about the individual context of the choice maker. It also does not provide the spatial details from GPS data. However, it provides a complete sample of route choices for specific OD pairs, which is crucial for this study. We therefore use a license plate survey.

Based on the hypothesis from Section 1, aggregated observations of revealed route choices and findings from the literature, we will select attributes, and use multinomial logit regression to study how these attributes influence the choice between center and orbital routes. Logit or related regression techniques have traditionally been used to model choice behavior in which choice makers are believed to "rationally" optimize their choices. However, cognitive sciences have shown that choice makers are not always optimizers. For example, they may consciously make choices that are satisfactory rather than optimal (Simon, 1955; Simon, 1978), and show risk aversion when they make decisions under uncertainty (Kahneman and Tversky, 1978). Theoretical models describing decisions under risk have also found their way in studies on travel choices, i.e., in the form of Prospect theory (e.g., Avineri and Bovy, 2008; Gao et al., 2010), and regret aversion (e.g., Chorus et al., 2008; Ben-Elia et al., 2012).

Although we will use standard terminology from random utility theory, our study does not necessarily support the underlying concept. On the contrary, our multinomial logit model should only be viewed as a useful regression technique to distinguish important determinants in route choice. Our study thus follows a more inductive approach, in which proper regression and validation techniques are used to study route choice within a specific spatial context. Although the model does not follow from behavioral theory, we will discuss how the results might be interpreted within the theoretical context.

3. Description of the survey

We used a license plate survey in the city of Enschede from June 2008. Although this city with almost 160 thousand inhabitants is rather large in the Dutch context (11th in size in the Netherlands), it can be considered a medium sized European town.